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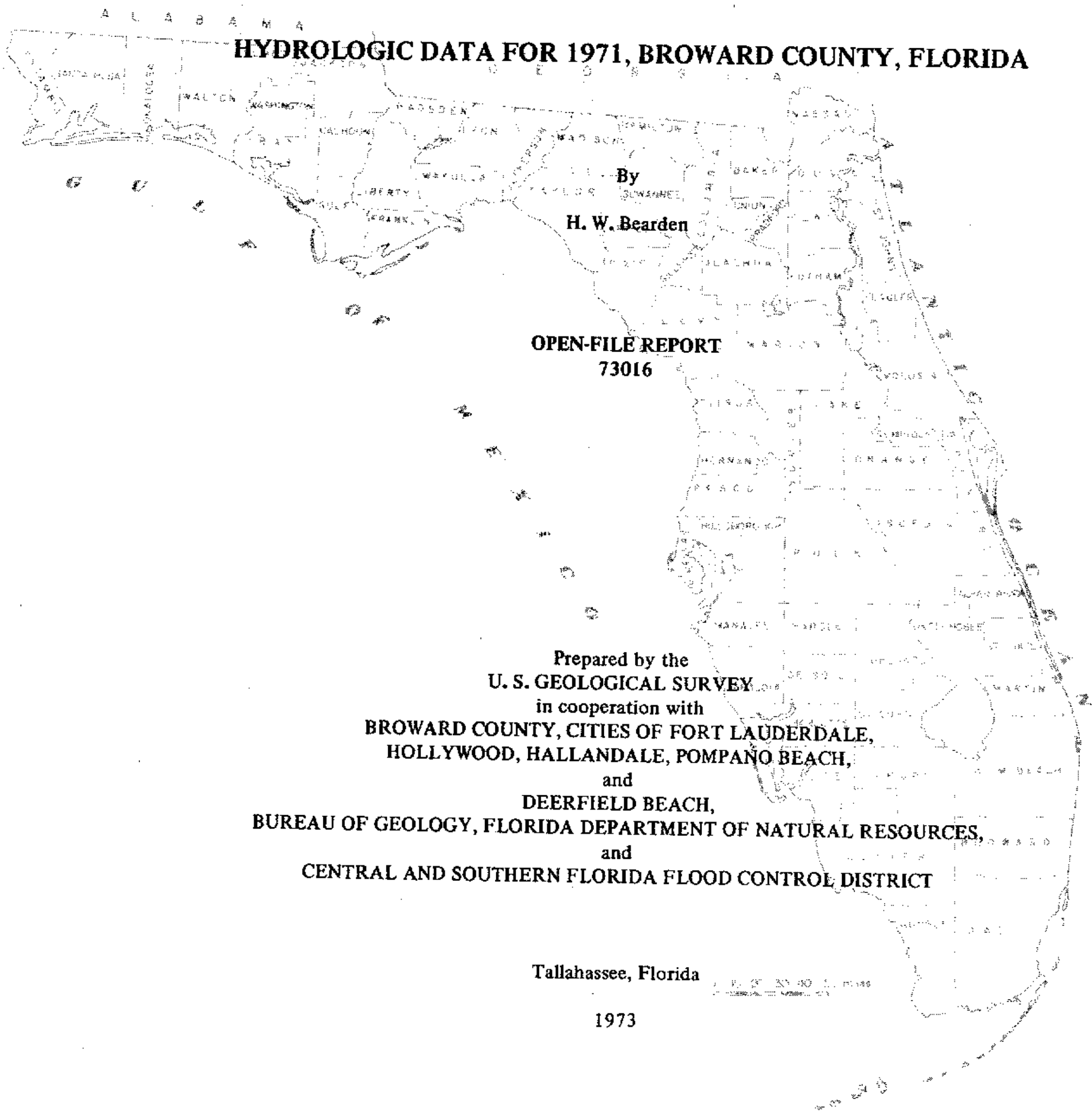
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROLOGIC DATA FOR 1971, BROWARD COUNTY, FLORIDA



By

H. W. Bearden

OPEN-FILE REPORT
73016

Prepared by the
U. S. GEOLOGICAL SURVEY
in cooperation with
BROWARD COUNTY, CITIES OF FORT LAUDERDALE,
HOLLYWOOD, HALLANDALE, POMPANO BEACH,
and
DEERFIELD BEACH,
BUREAU OF GEOLOGY, FLORIDA DEPARTMENT OF NATURAL RESOURCES,
and
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT

Tallahassee, Florida

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INTRODUCTION

This report is the first of an annual series that will describe the hydrologic conditions in Broward County, Florida. The general hydrologic conditions in Broward County for the 1971 water year (October 1, 1970, to September 30, 1971) are portrayed by graphically comparing long periods of record from rainfall, ground-water, surface-water, and water-quality stations with records from these stations for the 1971 water year. Major changes in hydrologic conditions in any year generally are a direct result of the amount and distribution of rainfall during that year. Major areal changes in conditions which may be permanent, result from construction of canals for drainage, establishment of controls on canals, withdrawals, and other such actions.

The purpose of this report is to summarize hydrologic data on an annual basis for short-term water-management planning. For example, a year of persistently low water levels (little rainfall) requires different water-management planning for the subsequent year than a year of average or high water levels.

The cooperative program of water resources studies between the U.S. Geological Survey and the Broward County Board of Commissioners is conducted through the Water Resources Department and the Air and Water Pollution Control Board.

WATER MANAGEMENT

The FCD (Central and Southern Florida Flood Control District) canal network in Broward County (fig. 1) plays an important role in water management in the county. Flow in these primary canals is regulated on a daily basis to obtain optimum ground-water levels and storage for each season and to provide flood protection. Many secondary (drainage) canals in the county are interconnected to the FCD network (fig. 2). The Broward Water Resources Department is responsible for the secondary canal network and both agencies work together to effectively manage the county's water resource. When rainfall is excessive, water is discharged from the aquifer to the canal system and transported to the conservation areas or to the ocean; when rainfall is deficient, water is transported through the canal system from the conservation areas for aquifer recharge where ground-water use is high.

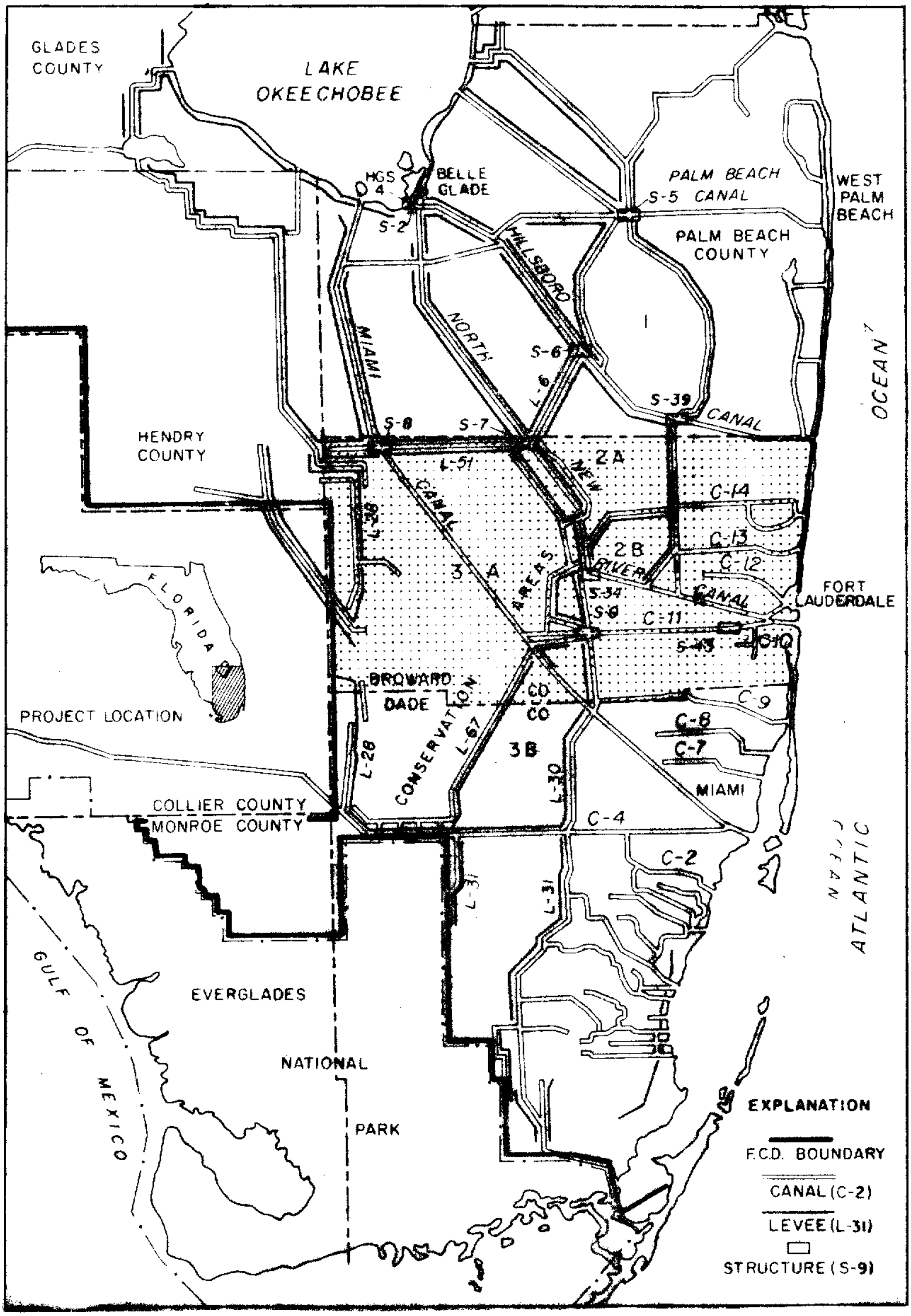


Figure 1.--Location of Broward County and the southeastern part of the Central and Southern Florida Flood Control District.

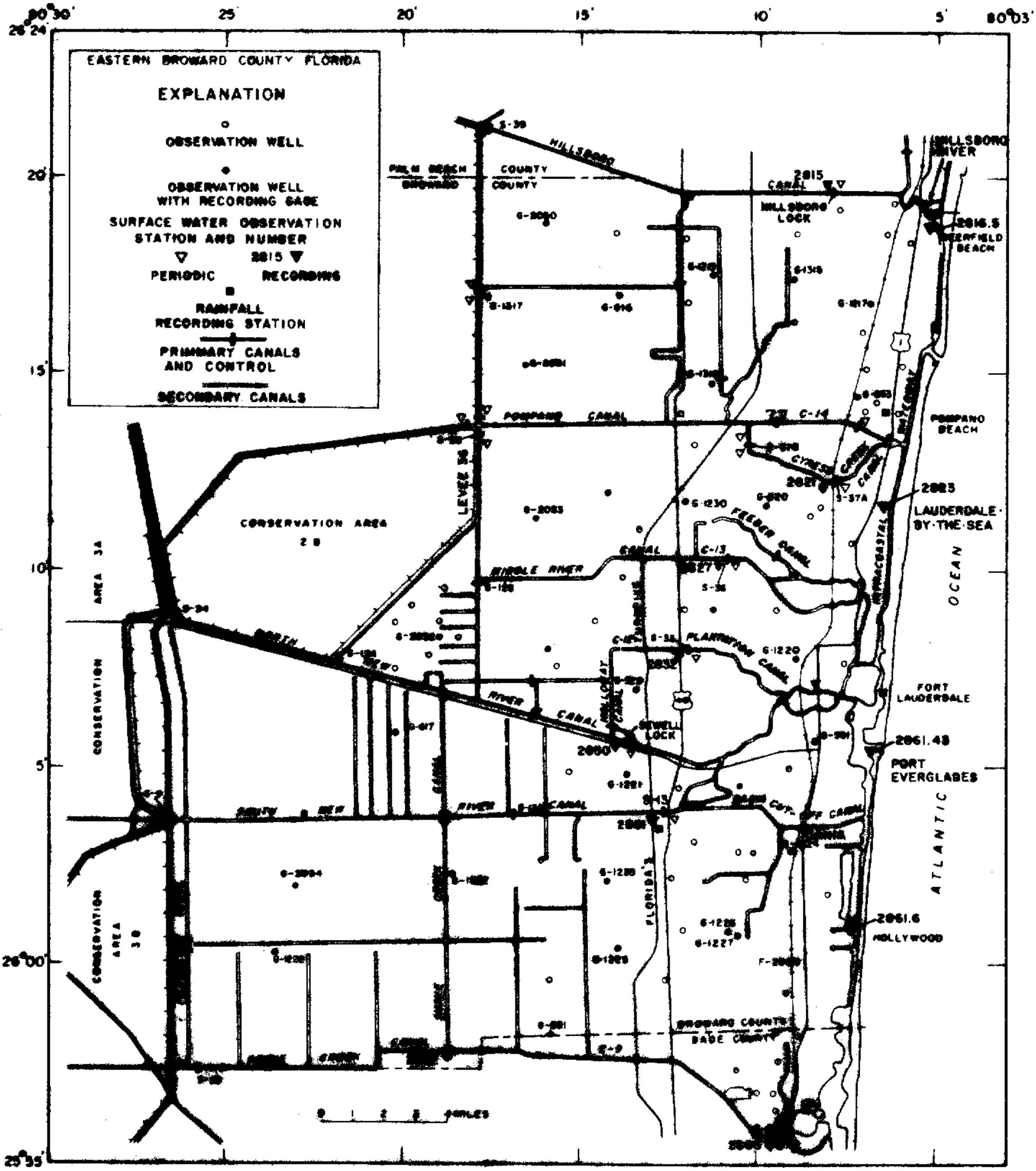


Figure 2.--Surface water gaging stations, rainfall stations, and observation wells in Broward County.

DATA COLLECTION

County-wide water-level fluctuations in the aquifer are monitored in 79 wells, 34 of which are equipped with recording instruments (fig. 2). Data from these wells help determine the effectiveness of the canal network in the county and aid in water management. Additional wells are located in municipal well field areas to monitor the effects of pumping.

A continuous record of stage and discharge was obtained from seven stream-gaging stations (fig. 2) in canals in Broward County during the 1971 water year. The record for one station in Dade County, Snake Creek Canal at S-29, is also discussed in the report. The stations except Snake Creek Canal at Northwest 67th Avenue (station 2862) are located at the eastern control structures in the canals. Tidal fluctuations in the Intracoastal Waterway are recorded at 4 stations (fig. 2).

Rainfall records from 4 stations in Broward County, 3 coastal and 1 inland station, are used in this report. The 3 coastal stations, Pompano, Fort Lauderdale, and Dania, are shown in figure 2. The inland station is located at the S-7 pump station on North New River Canal (fig. 1).

Samples for water-quality analysis are collected quarterly at 25 sites (fig. 3) in primary canals in Broward County. Samples for analysis of natural constituents, metals, nutrients, pesticides, and bacteria are collected at each site. The chemical constituents are commonly reported in milligrams per liter. Pesticides are generally reported in micrograms per liter. Field determinations of DO (dissolved oxygen), pH, temperature, specific conductance, and alkalinity are made at 4-hour intervals during a 24-hour period each quarter at the 25 sites.

Samples for chloride analysis are collected monthly at the salinity control structures and at selected sites in the tidal canals (fig. 3) and conductivity recorders are maintained in three canals near major well fields.

Water samples for chloride analysis are collected semi-annually from the wells shown in figure 3 to determine the position of the salt front in the aquifer and to monitor its movement.

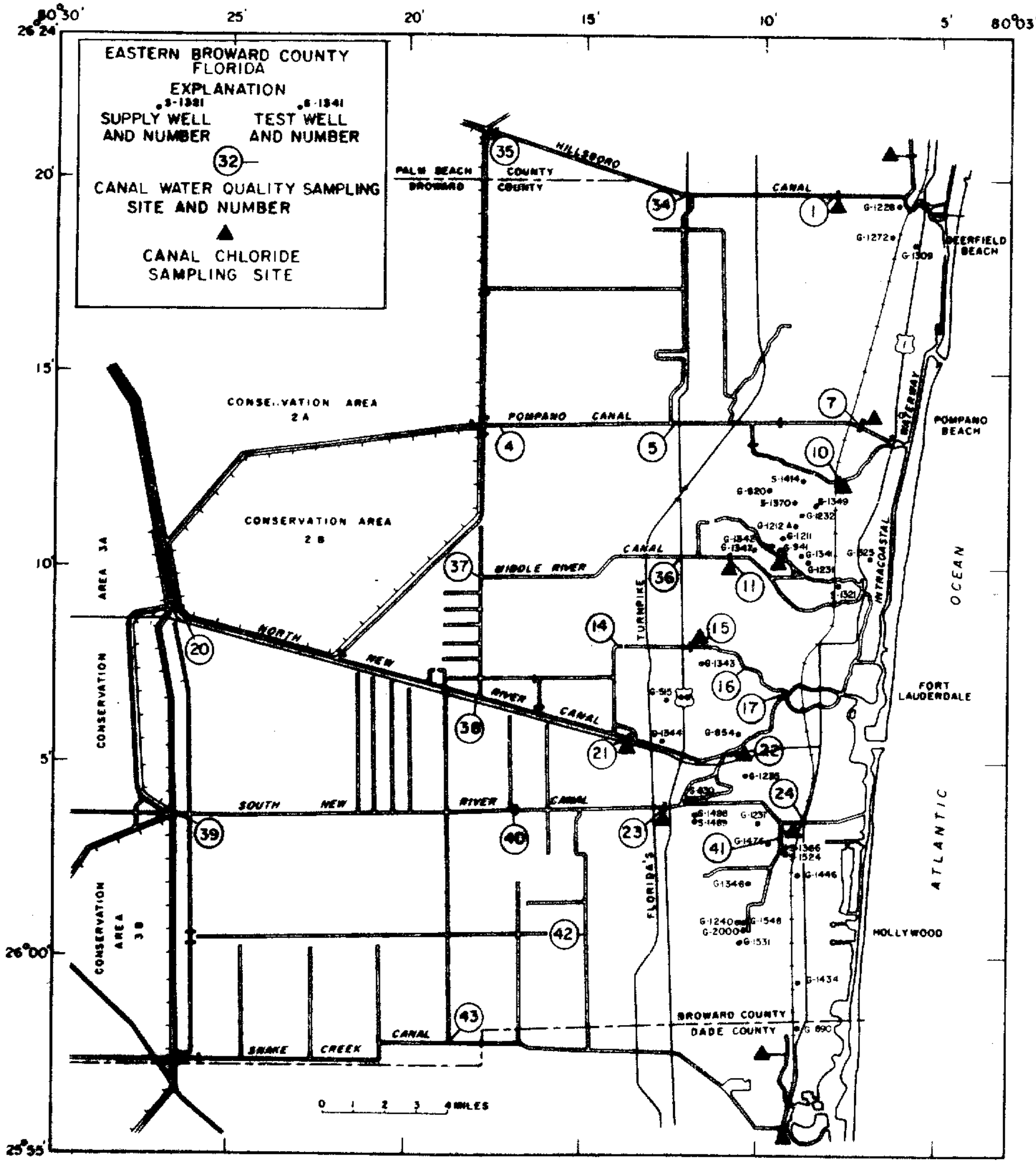


Figure 3.--Location of wells sampled for chloride analysis and selected water quality sampling sites in the canal system.

RAINFALL

The average annual rainfall in Broward County, based on 28 calendar years of record (1943-1970), is 59.10 inches (table 1). Rainfall averaged 35.86 inches during the 1971 water year; 23.24 inches and 39 percent below the 28-year average. The average annual rainfall at the four stations varies from 63.43 inches at Fort Lauderdale in the eastern sector to 51.71 inches at North New River Canal in the western sector. Rainfall also varies within a year. The 5 months, June-October, usually account for more than 60 percent of the yearly total. The 31.93 inches at Fort Lauderdale (table 1) for the 1971 water year was the lowest for the 28-year record at that station.

Rainfall was deficient during the first 11 months of the 1971 water year and slightly above average in September (fig. 4). During November-April, rainfall was 80 percent below the 28-year average, the result of a severe drought. During the latter part of the drought the quantity of water used by the public was voluntarily reduced in most areas.

Table 1.--Summary of rainfall data by stations.

Location	1971 Water Year	Calendar Year Average (1943-70)
Eastern sector (coastal):		
Dania	33.18	58.14
Fort Lauderdale	31.93	63.43
Pompano	34.76	63.13
Western sector:		
North New River Canal at S-7	43.57	51.71
Average of above stations	35.86	59.10

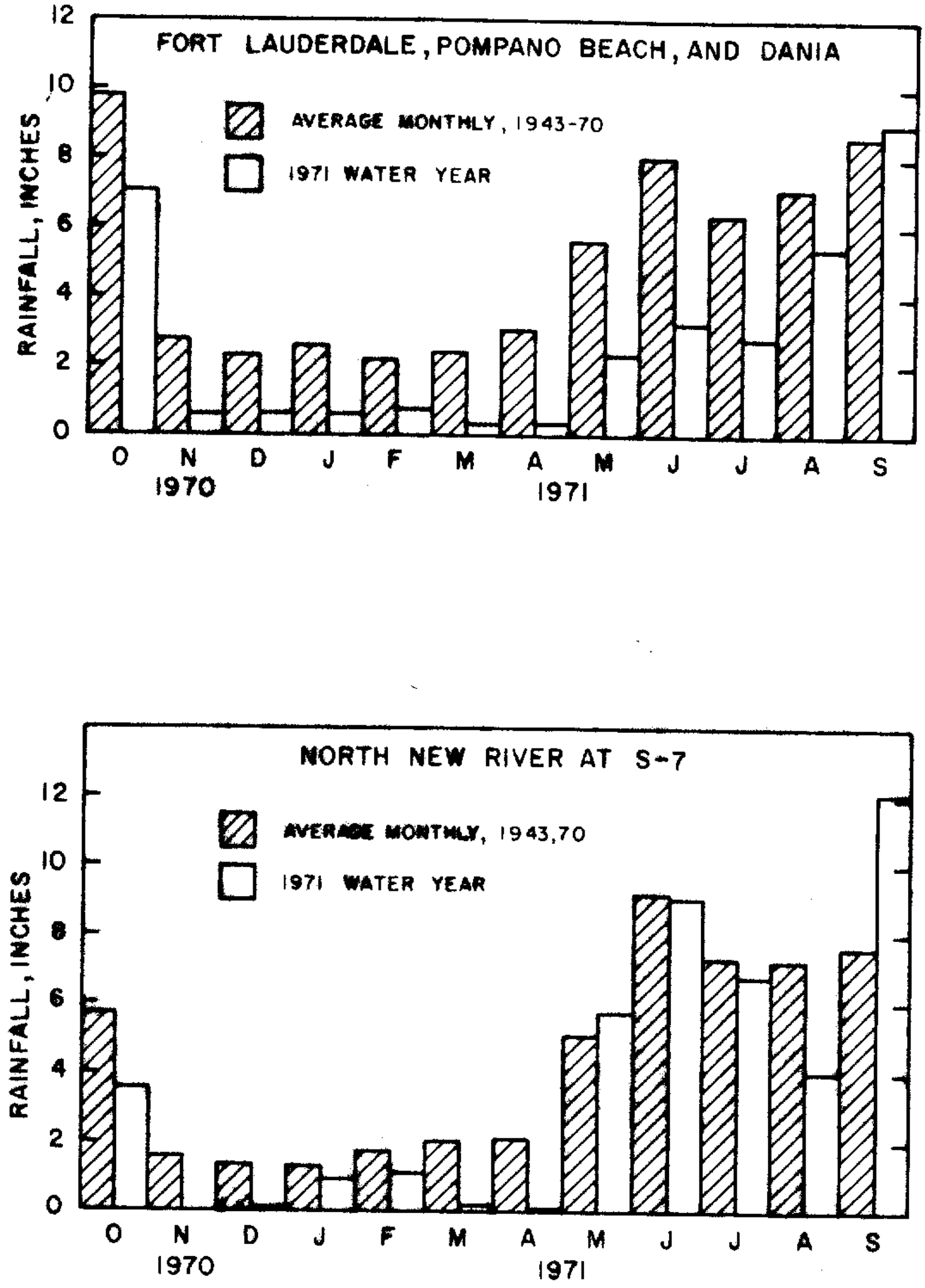


Figure 4.--Monthly rainfall for the 1971 water year and the average monthly rainfall, 1943-70, at Fort Lauderdale, Pompano, and Dania and at North New River canal at S-7.

GROUND WATER

Ground water is the water in the zone of saturation--the zone in which the interstices, joints, crevices, fissures, solution holes, and all other voids are filled with water. A formation, group of formations, or part of a formation that contains sufficient saturated material to yield significant quantities of water to wells, are called aquifers (Lohman and others, 1972). The Biscayne Aquifer is the source of all fresh ground water in Broward County.

The Biscayne aquifer in Broward County is composed chiefly of permeable limestone, sandstone, and sand that range in age from late Miocene through Pleistocene (Sherwood and others, 1973). The aquifer extends from land surface to more than 200 feet along the coastal areas of Broward County and decreases in thickness westward until it pinches out at the surface near the Collier-Broward County line. The aquifer is underlain by massive beds of marine sediments and marl of low permeability.

The amount of fresh ground water potentially available in the aquifer is determined by the recharge to and discharge from the aquifer and the quantity available from storage. Infiltration of rainfall through surface materials and seepage from controlled canals and the conservation areas constitute the recharge. Discharge from the aquifer occurs by evapotranspiration, by ground-water flow to canals and the ocean, and by pumping from wells.

Rainfall is the major source of recharge, thus, area-wide water levels in the aquifer fluctuate chiefly in reponse to variations in rainfall (figs. 5 and 6). During the wet season, water levels in the aquifer are high; during the dry season, water levels are low. The 1971 water year was extremely dry, especially November-April. Consequently, water levels during the year were near or below the extreme monthly lows for the previous years of record in almost all wells not influenced by canals (figs. 5-8).

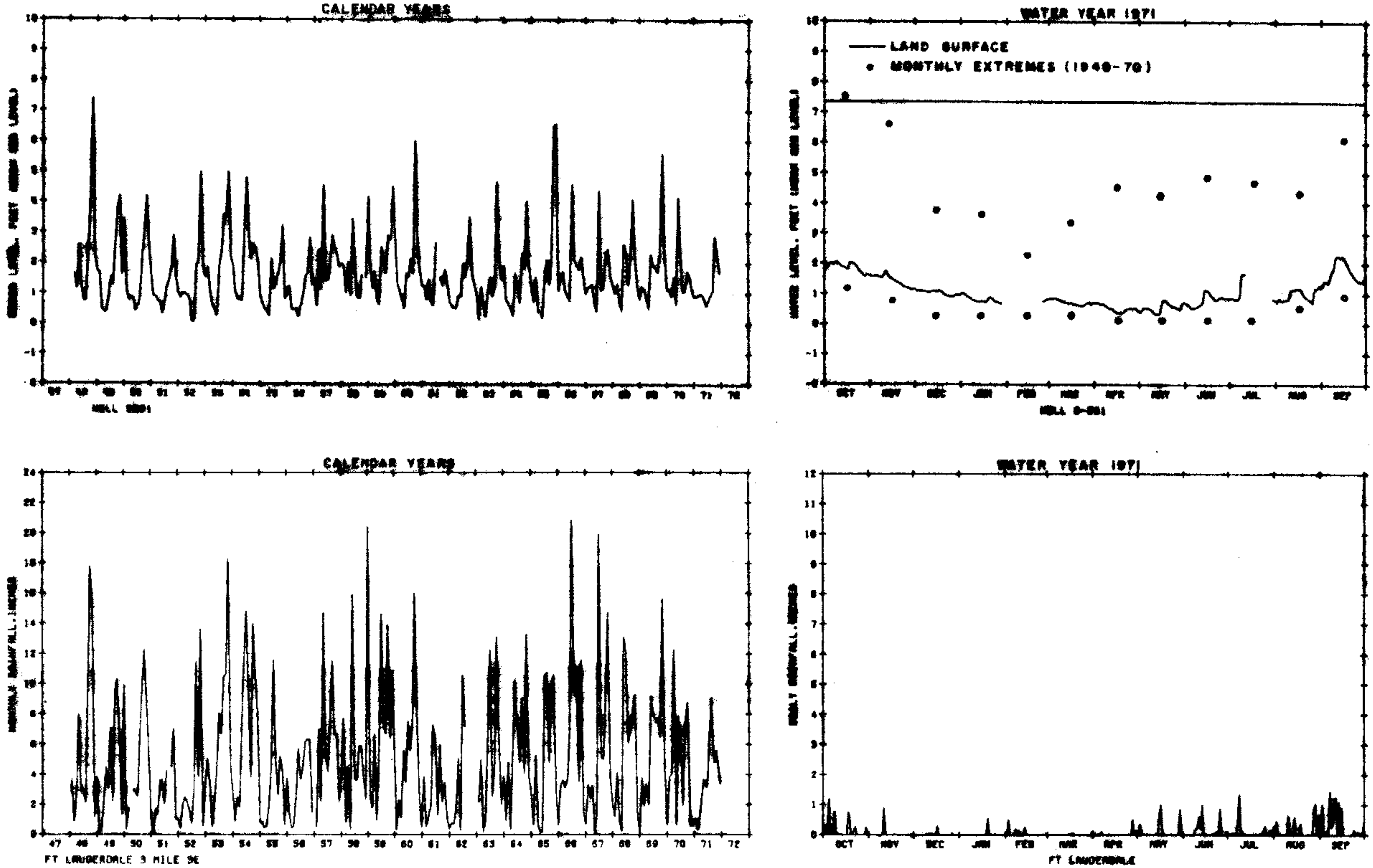


Figure 5.--Hydrographs of well G 561 and rainfall at Fort Lauderdale for the 1971 water year and 1948-71 calendar years.

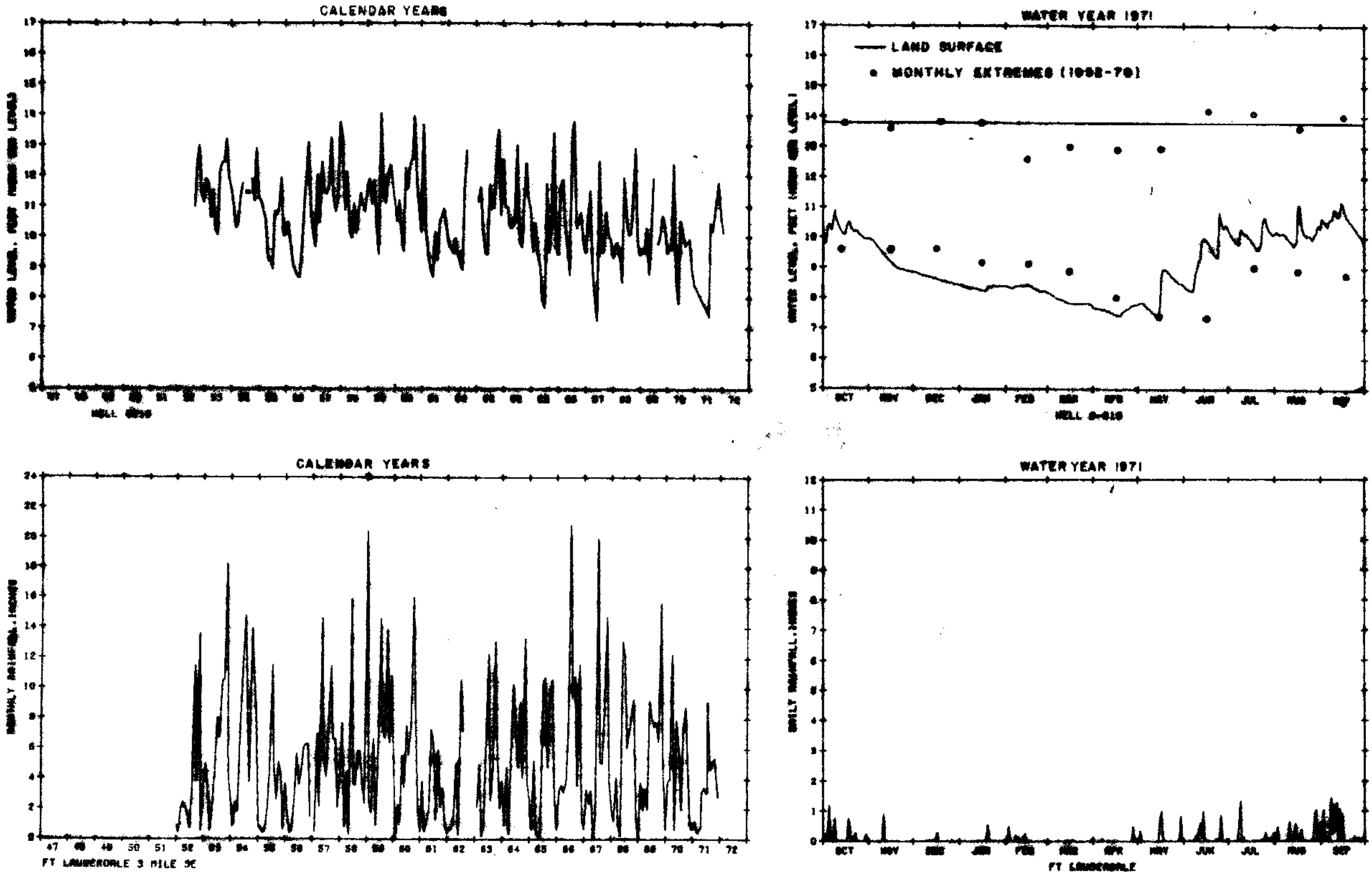


Figure 6.--Hydrographs of well G 616 and rainfall at Fort Lauderdale for the 1971 water year and 1952-71 calendar years.

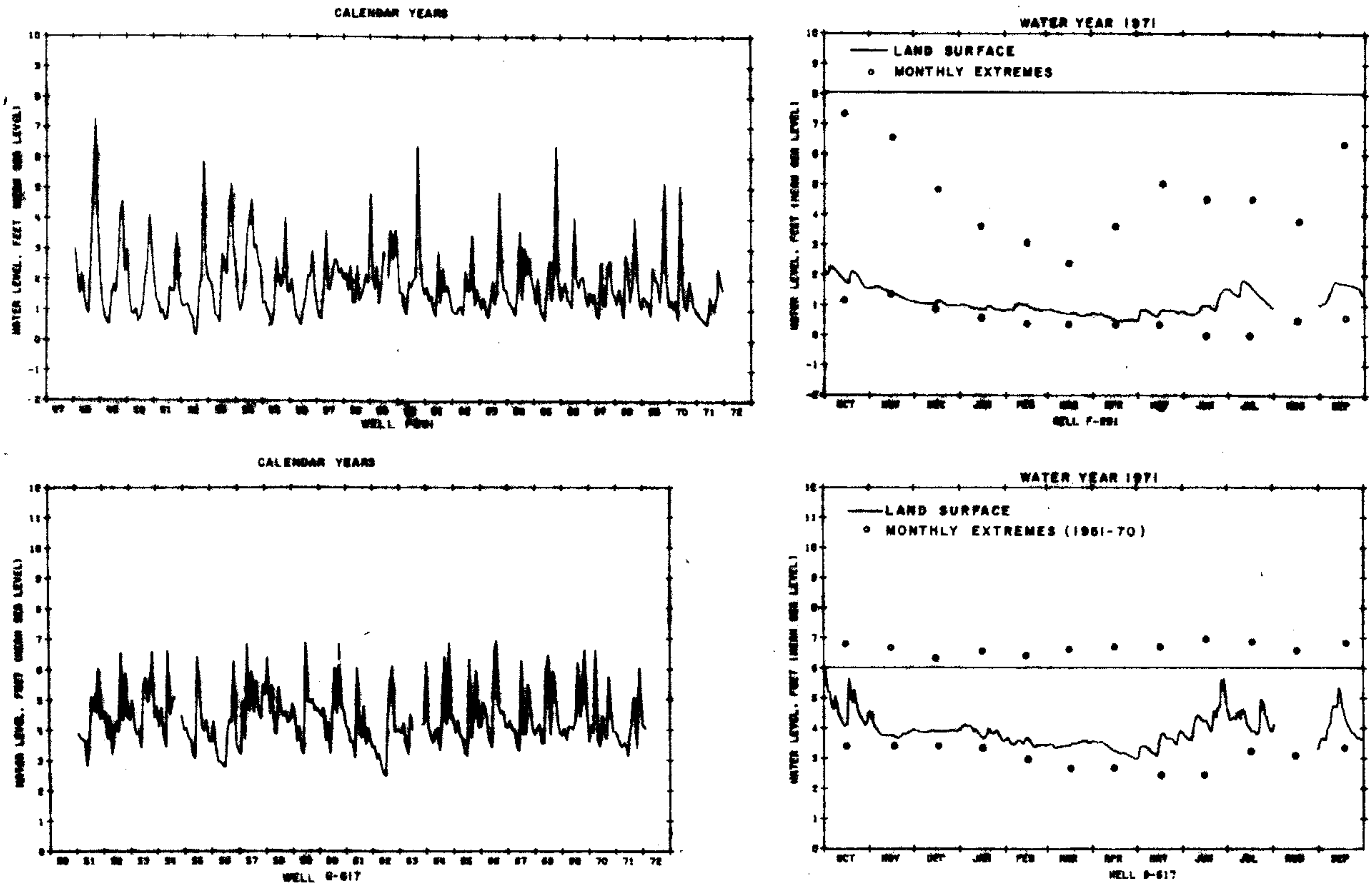


Figure 7.--Hydrographs of wells F-291 and G-617 for the 1971 water year and 1948-71 and 1951-71 calendar years, respectively.

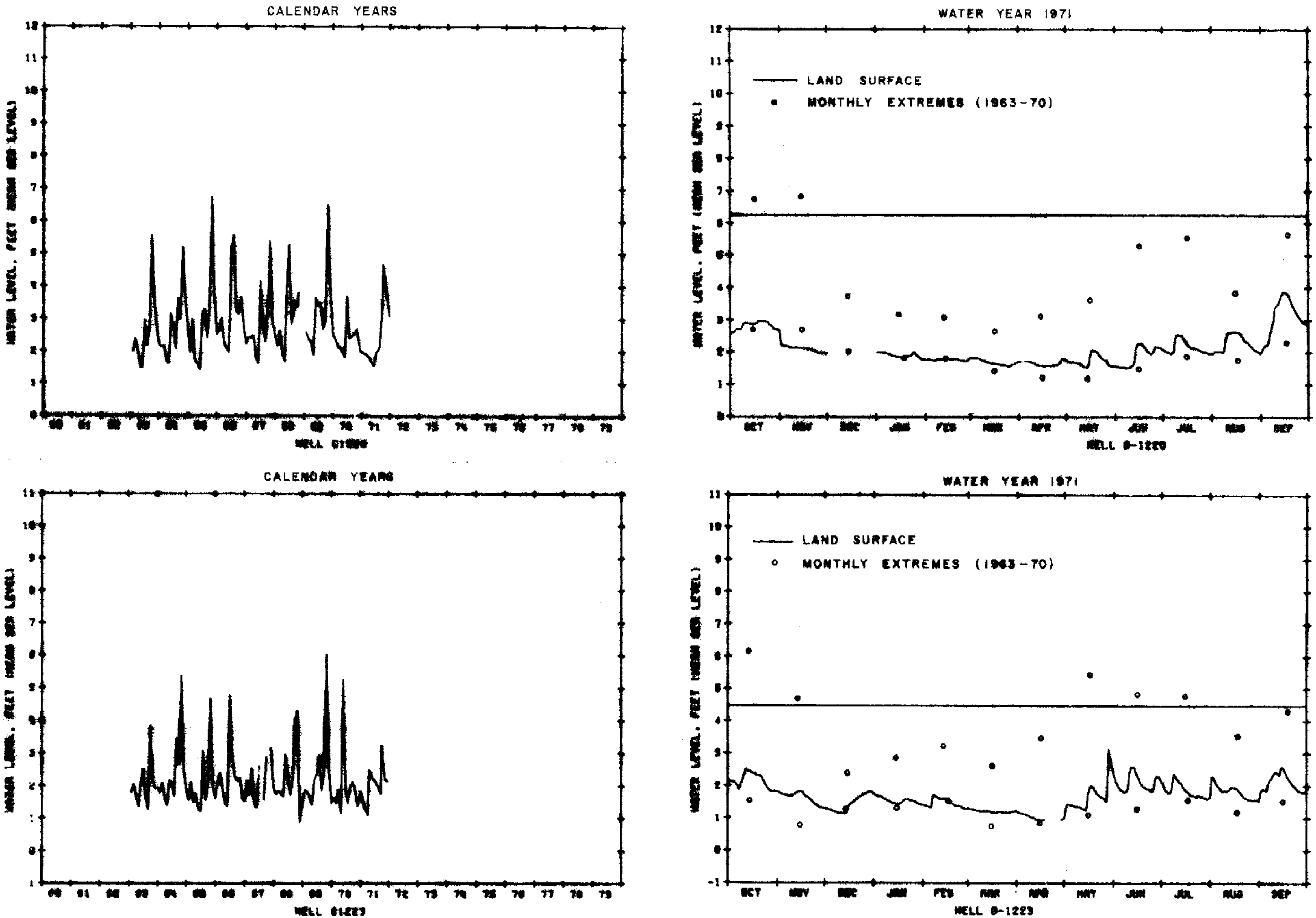


Figure 8.--Hydrographs of wells G 1220 and G 1223 for the 1971 water year and 1963-71 calendar years.

To prepare water-level contour maps, water-level measurements are made in the observation wells in Broward County (fig. 2) during the wet and dry seasons each year to obtain the extreme aquifer conditions for the year. The configuration of the water table, the hydraulic gradients, and the general direction of ground-water movement can be determined from the contours. Record high levels on November 1, 1965 (fig. 9) were the result of several days of heavy rainfall during a hurricane. Record low levels on May 5, 1971 (fig. 10) were the result of several months of deficient rainfall and heavy withdrawals from wells during the period. The high water levels for 1971 (fig. 11) are about average for the wet season. Water levels in the vicinity of U.S. Highway 441 and Hillsboro Canal are regulated by a local drainage district which pumps water from Hillsboro Canal into the secondary canals in the area to maintain fairly high water levels year round.

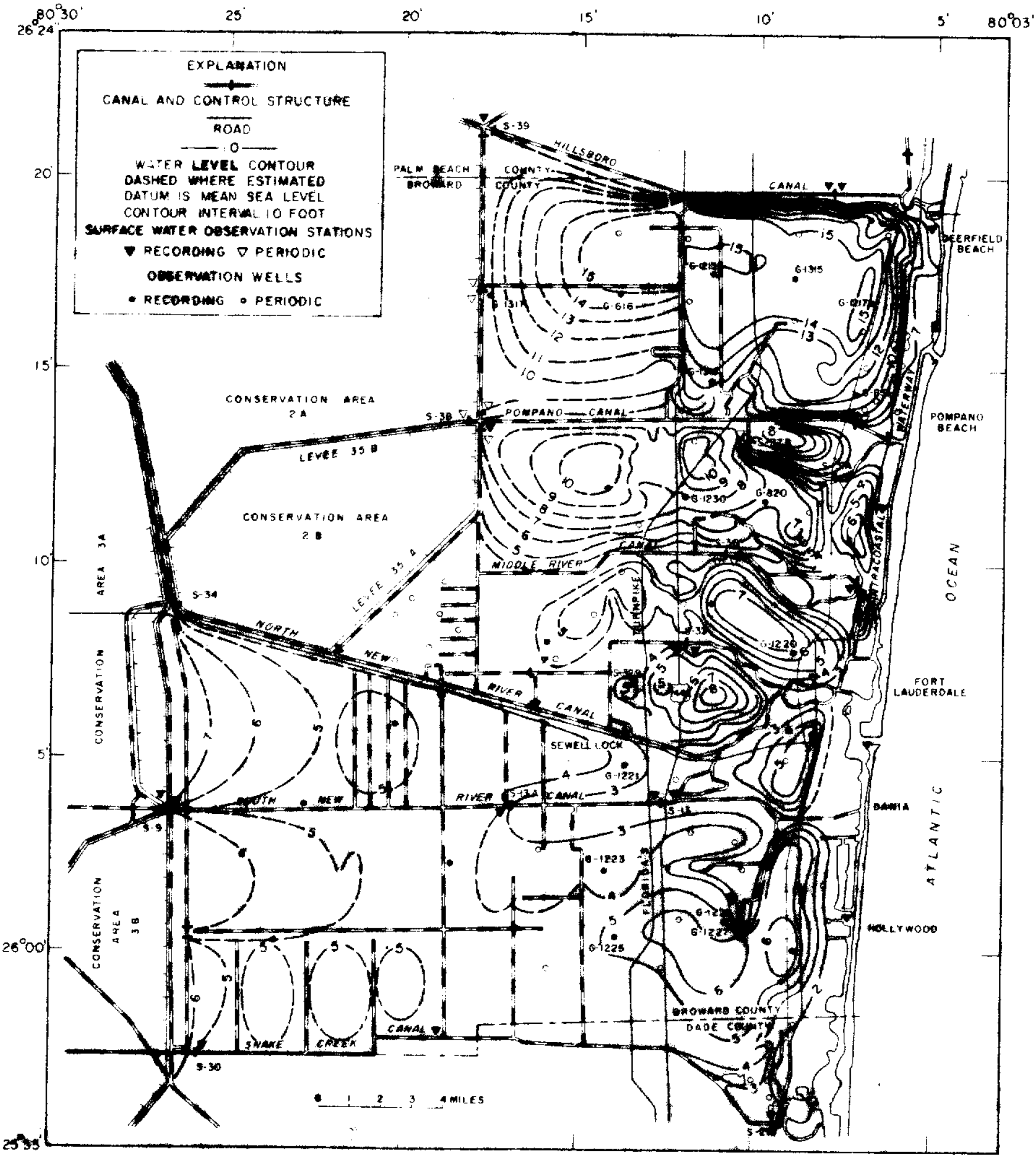


Figure 9.--Water-level contour map of eastern Broward County during record high conditions, November 1, 1965.

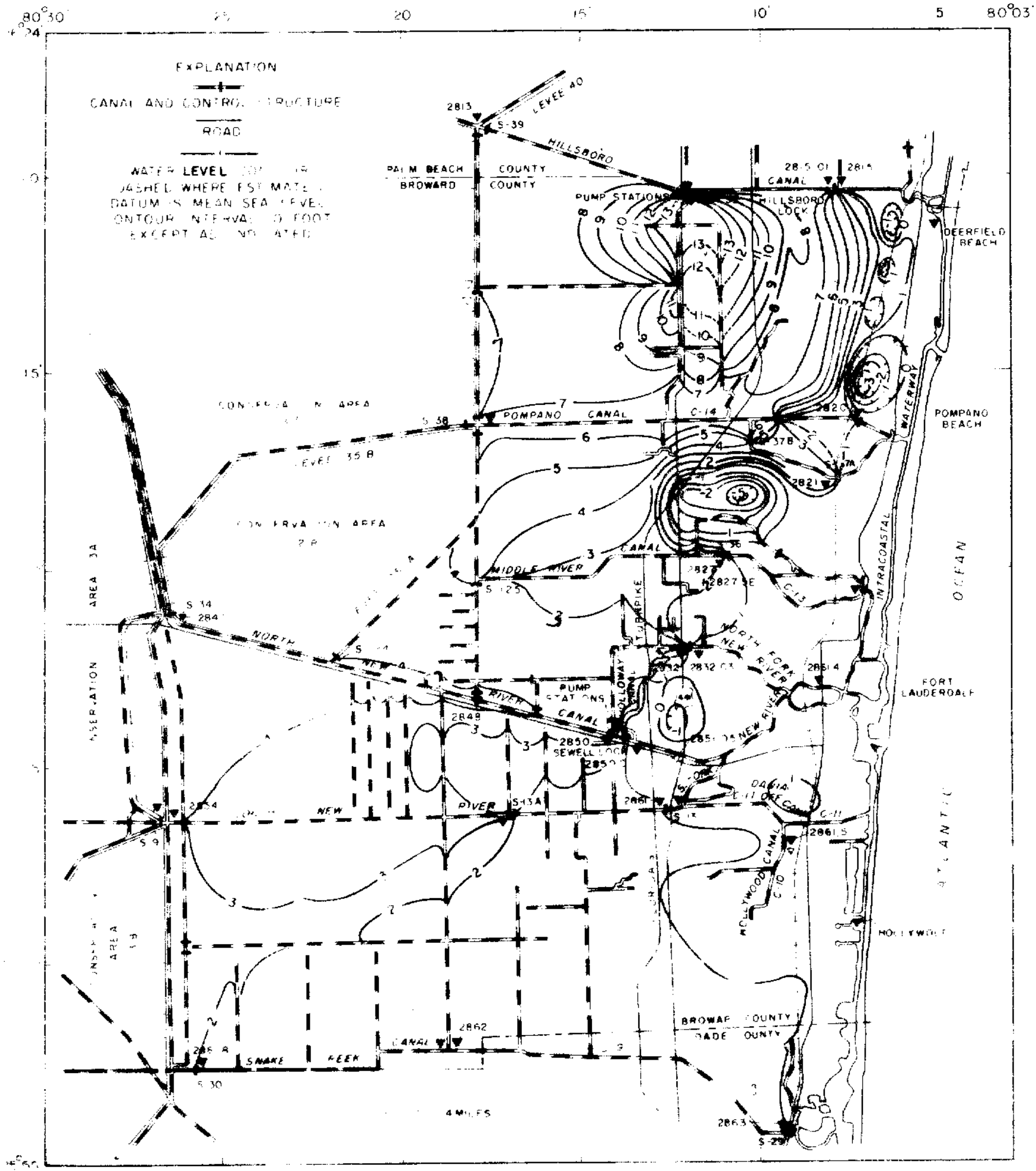


Figure 10.-- Water-level contour map of eastern Broward County under record low conditions, May 5, 1971.

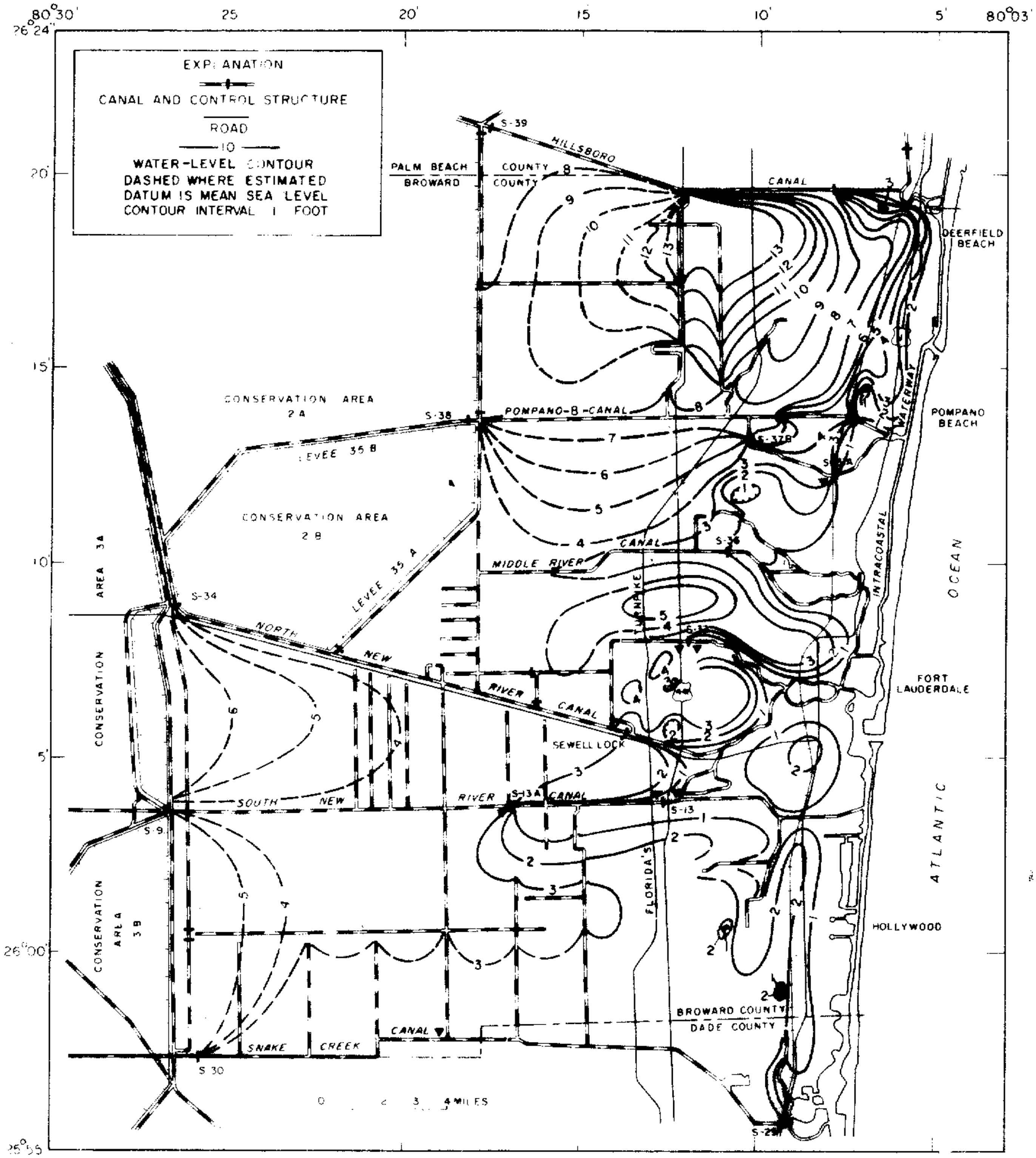


Figure 11.--Water-level contour map of eastern Broward County during high water conditions, October 19, 1971.

The record lows prior to May 5, 1971 occurred on May 21-22, 1962, after a period of deficient rainfall and heavy ground-water withdrawals. Water levels in the Pompano Beach, Fort Lauderdale Dixie, and Fort Lauderdale Prospect well fields on May 5, 1971 (figs. 12 through 17), were much lower than in 1962, reflecting the increased water demand since 1962. The low levels in 1971 indicate the need to constantly monitor water levels in the area to aid in planning pumping schedules to prevent excessive withdrawals from the aquifer during dry periods.

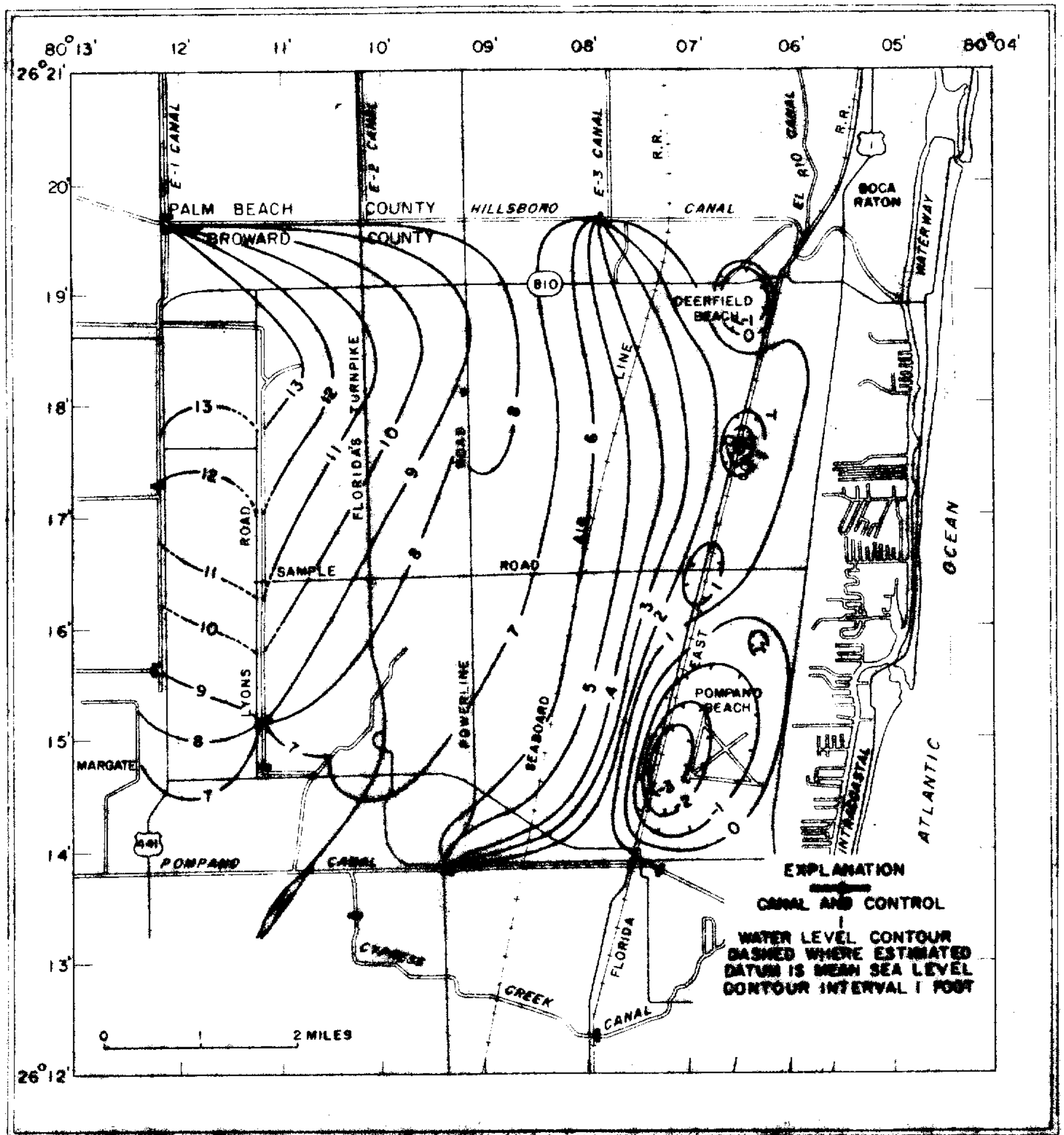


Figure 12.--Water-level contour map of the Pompano Beach well field and surrounding area during record low conditions, May 5, 1971.

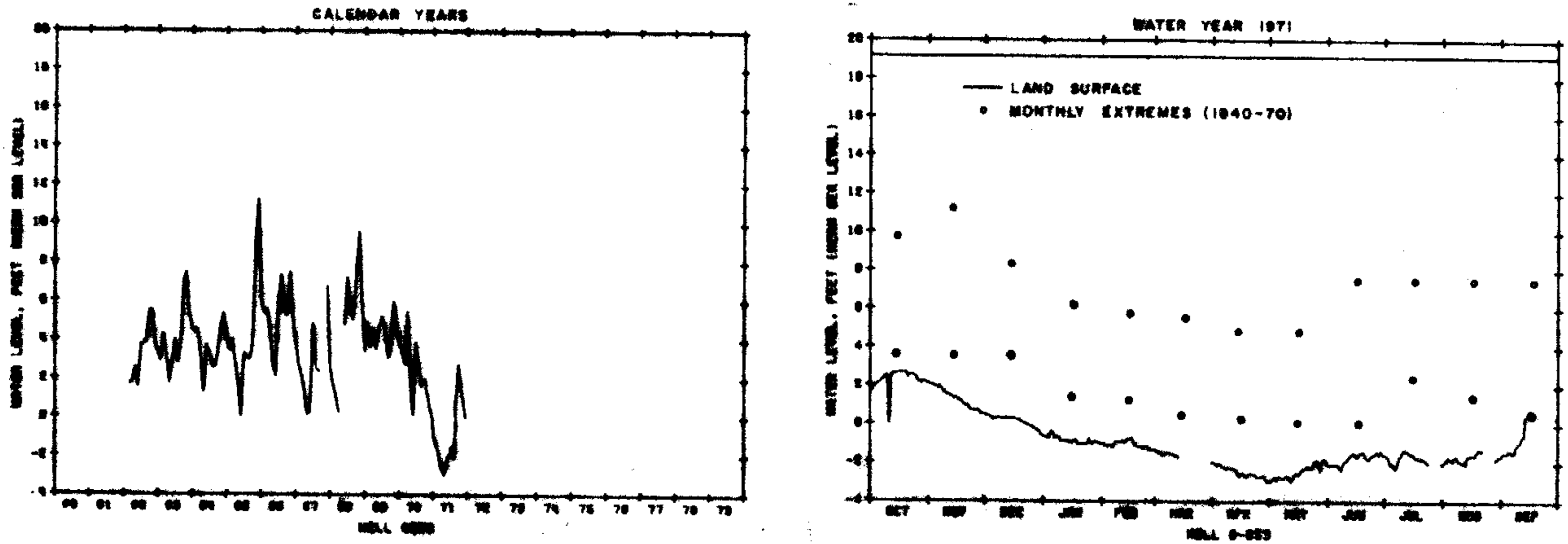


Figure 13 .--Hydrographs of well G 853, Pompano Beach well field, for the 1971 water year and 1962-71 calendar years.

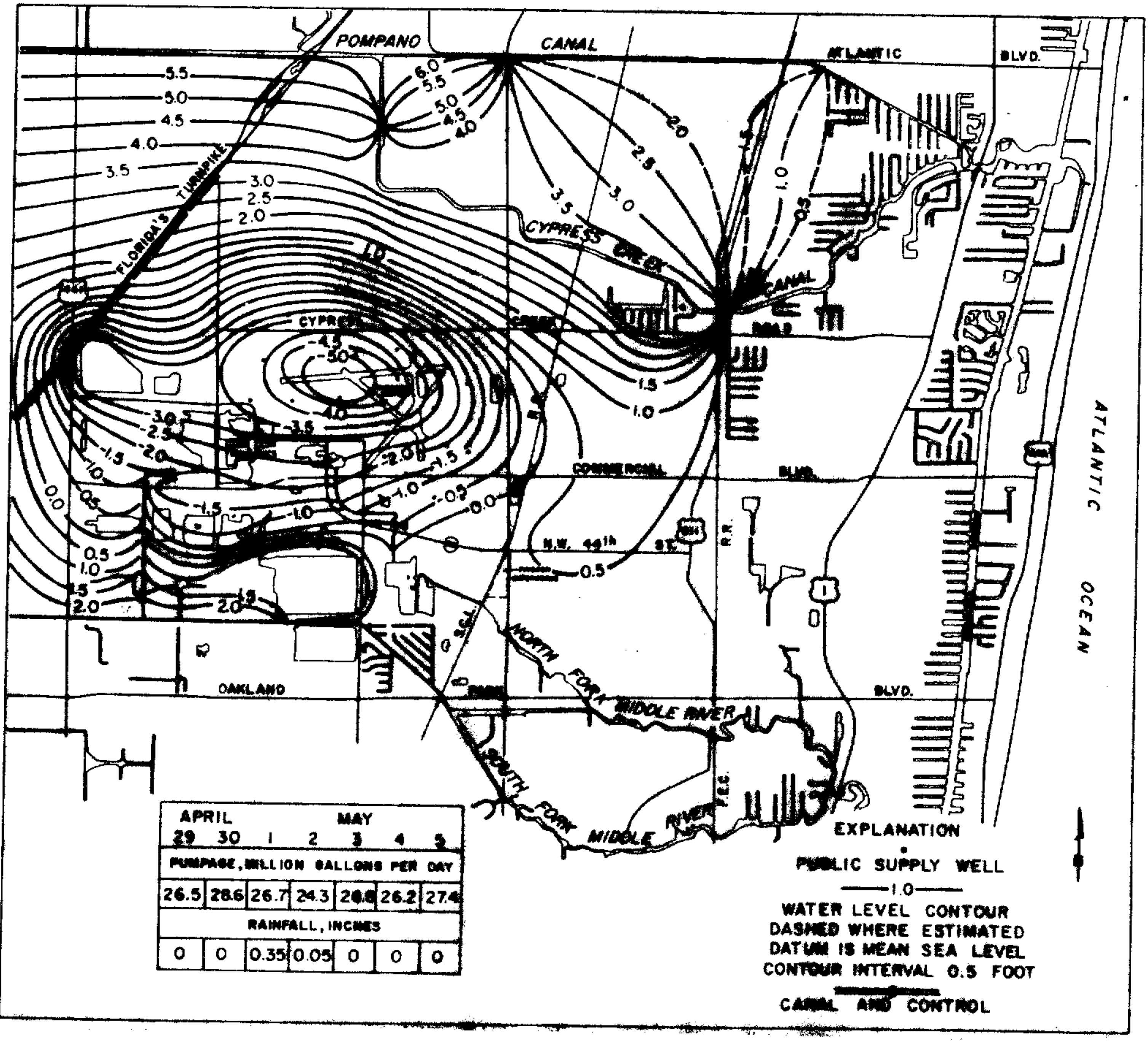


Figure 14.--Water-level contour map of the Fort Lauderdale Prospect well field and surrounding area during record low conditions and peak pumpage, May 5, 1971.

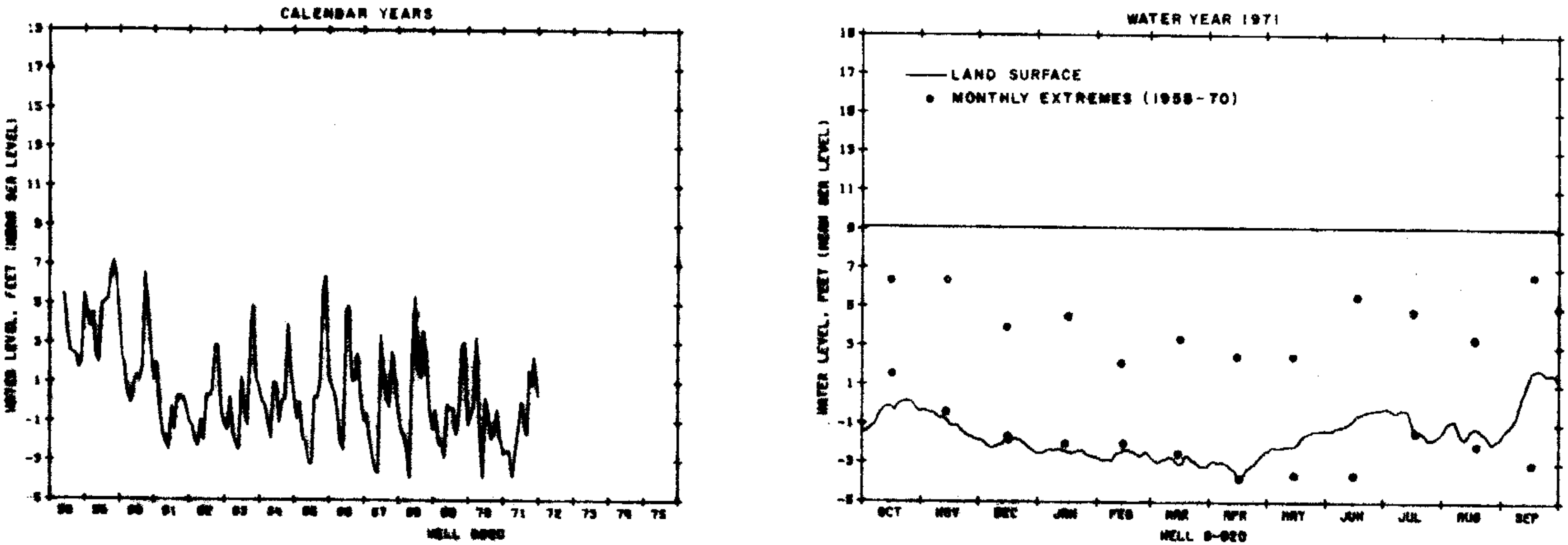


Figure 15 .--Hydrograph of well G 820, Fort Lauderdale Prospect well field, for the 1971 water year and 1958-71 calendar years.

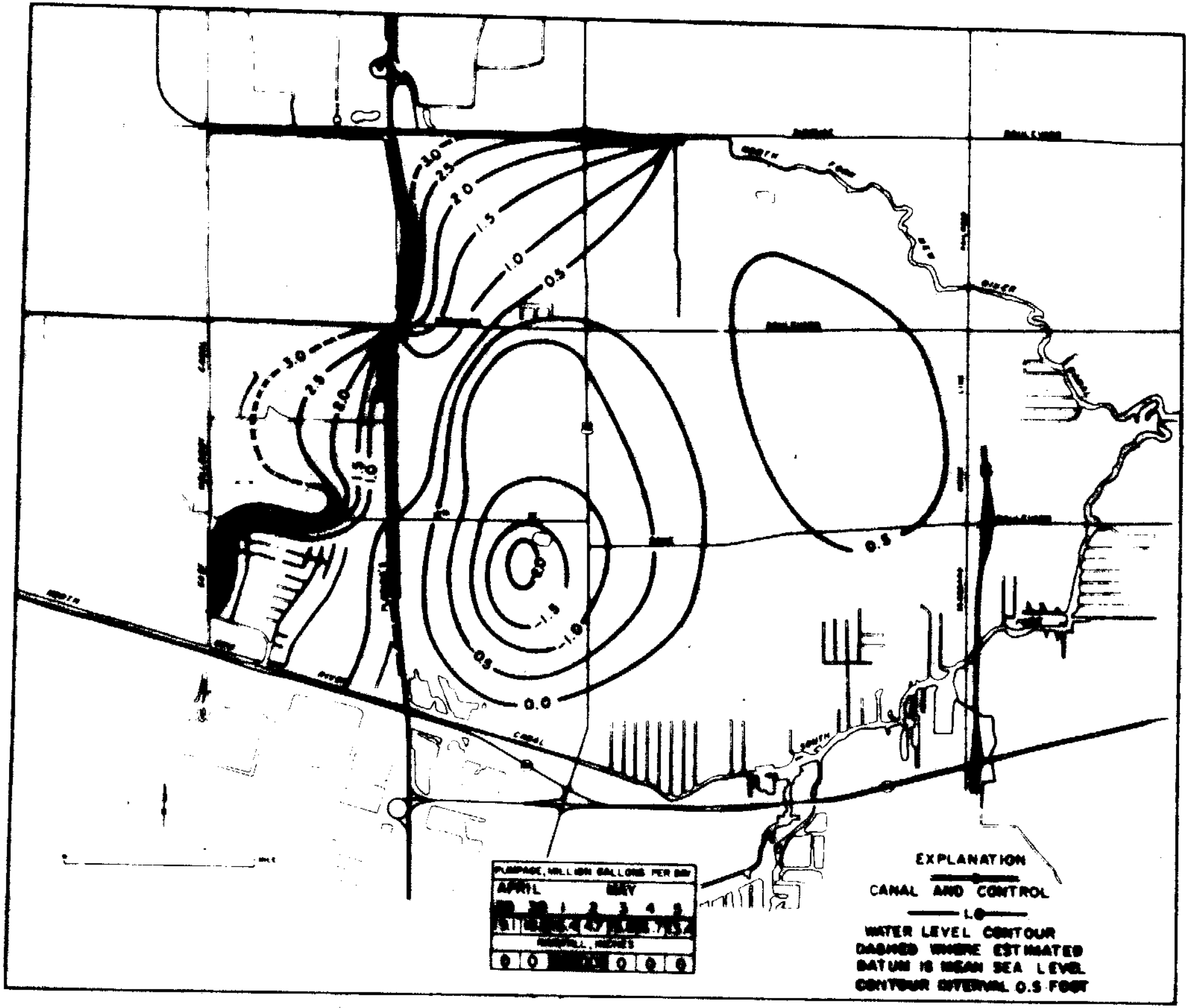


Figure 16 --Water-level contour map of the Fort Lauderdale Dixie well field and surrounding area during record low conditions and peak pumpage May 5, 1971.

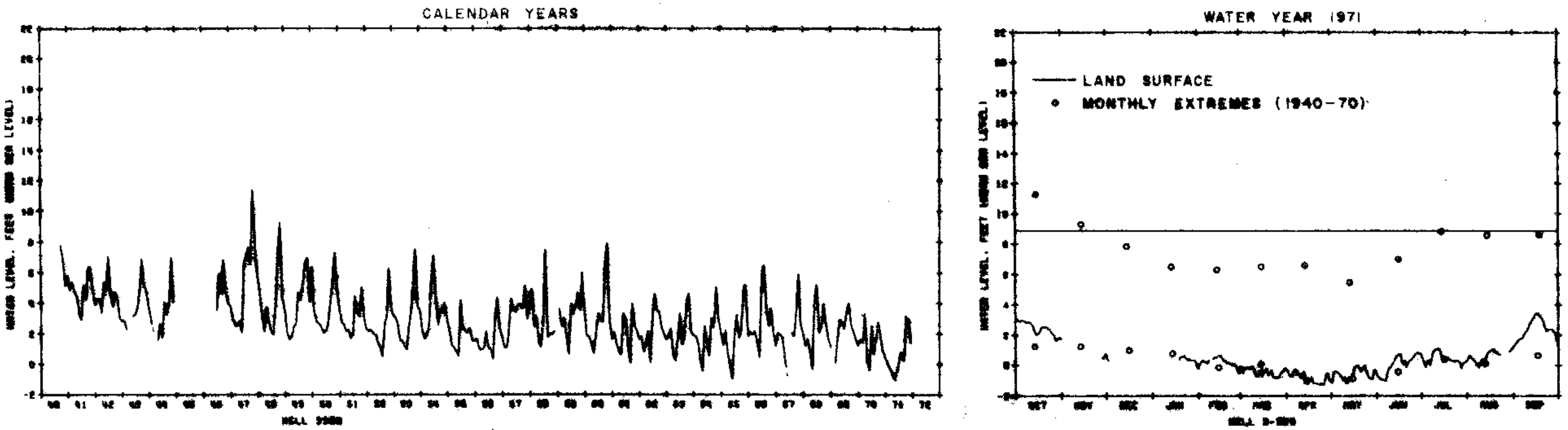


Figure 17 --Hydrographs of well S-329, Fort Lauderdale Dixie well field, for the 1971 water year and 1941-71 calendar years.

SURFACE WATER

Discharge throughout the surface flow system in Broward County was dependent on the intensity and duration of rainfall until the establishment of the water-management system in the County. Major modifications to the regional canal system in Broward County began about 1953 and were virtually complete by 1962. The extreme flows have been greatly modified and the duration of moderate or optimum flows greatly lengthened.

The water conservation areas (fig. 1) constructed in the Everglades in the western part of Broward County serve to impound water for use in the coastal areas and the Everglades National Park during the dry periods, and to help maintain high fresh water heads along the coast to prevent salt-water intrusion. In addition to rain that falls on the conservation areas and water that is conveyed into the areas from Lake Okeechobee and the upgradient part of the management system, excess water from the coastal areas may be backpumped into storage at pump station S-9 on South New River Canal (fig. 2). During droughts Broward County's fresh-water supply is chiefly dependent on the regional water-management system and the canal network.

Discharge

Stage-discharge relations are used to obtain a continuous record of flow at all stations except South New River Canal at S-13 and Snake Creek Canal at Northwest 67th Avenue where deflection meters are the most effective means of obtaining flow records. Determining flows in the highly controlled canal system has been greatly aided by the cooperation of the FCD and Broward Water Resources Department in furnishing logs of control changes.

Discharge measurements are made periodically in the canals at the stream-gaging stations to determine whether the stage-discharge or the stage and deflection-discharge relation is remaining constant or is changing. Very few measurements were made during the 1971 water year because of the long periods of no flow in many of the canals.

Because major modifications to the regional water-management system were not complete until 1962, discharge data from 1962-70 were used to compile duration curves and mean discharges for each month to compare with the 1971 duration curve and monthly mean discharges.

Hydrographs of canal discharge and stage show trends and extremes for the period of record. Monthly discharge values were plotted on the long-term hydrographs and daily values are plotted on the hydrographs for the 1971 water year. Maximum and minimum daily mean stage for each month were plotted on the long-term hydrographs and daily mean stages are plotted on the hydrographs for the 1971 water year.

Hillsboro Canal

Hillsboro Canal is one of the major canals in the FCD netowrk (fig. 1). The canal is 52 miles long, extending from Lake Okeechobee through Conservation Area 1 and the urban area to the ocean. At the eastern boundary of Area 1, flow through the Hillsboro Canal is regulated by structure S-39. Flow released at S-39 enters Broward County 10 miles west of Deerfield Beach and travels east to the Deerfield Lock and Dam, where it is regulated through the lock chamber and five spillways that constitute the dam.

The yearly mean discharge from the Deerfield Lock and Dam of 65 cfs (cubic feet per second) for the 1971 water year was slightly higher than the lowest yearly mean discharge for the 32 years of record, 58 cfs, in 1956 (fig. 18). Monthly mean discharges for the 1971 water year were far below the mean monthly discharges for 1962-70 for each month except October, May, and September. Daily discharge exceeded 240 cfs 10 percent of the time during 1962-70 and exceeded 140 cfs 10 percent of the time during 1971.

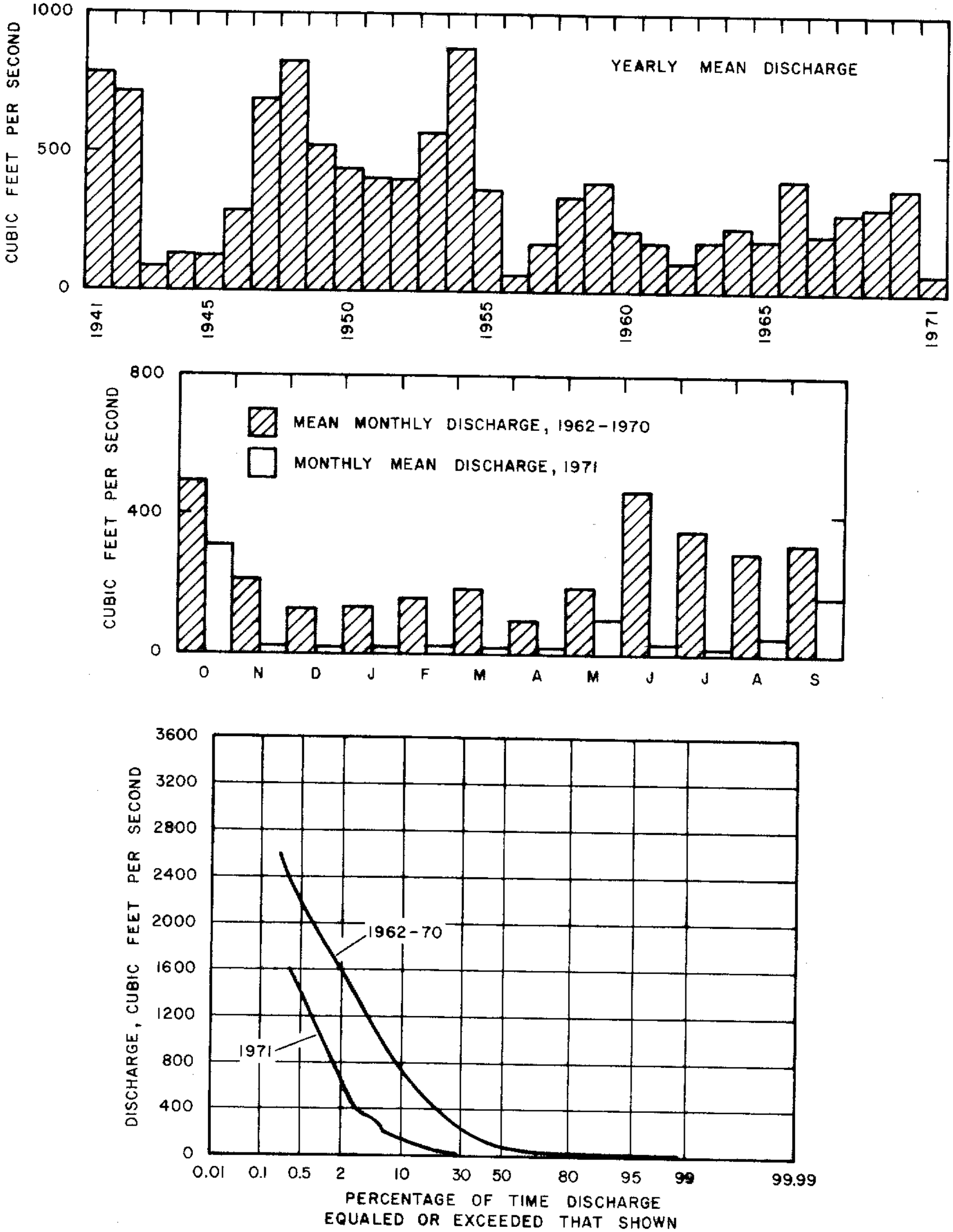


Figure 18 --Discharge data and flow-duration curves for the Hillsboro Canal near Deerfield Beach.

The stage at the lock and dam was held above 6.0 feet msl (mean sea level) during most of the 1971 water year (fig. 19) to replenish the aquifer to prevent salt-water encroachment and provide irrigation water for the farms to the west. As a result of low rainfall and the high stage maintained at the lock and dam, discharge was extremely low.

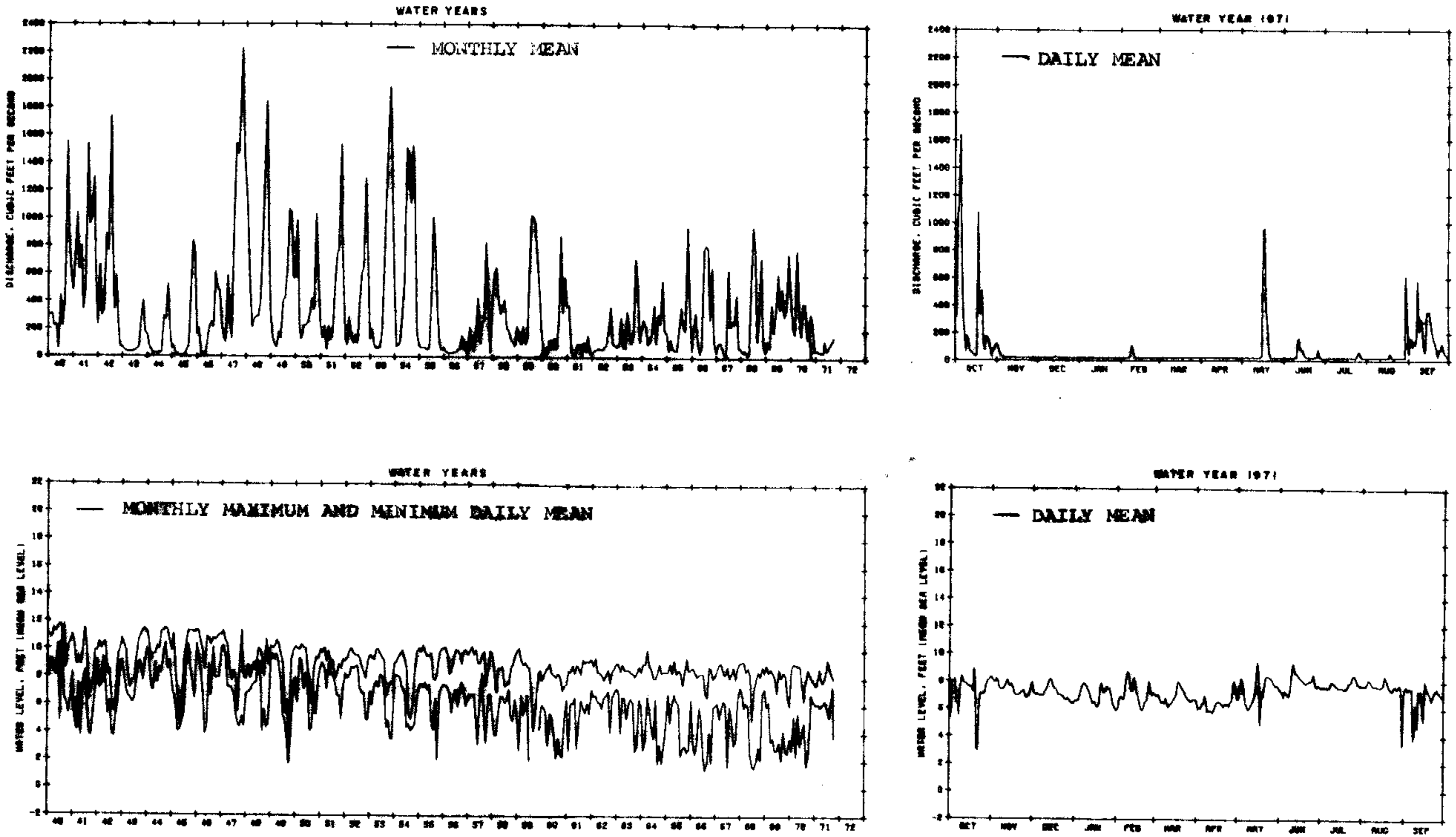
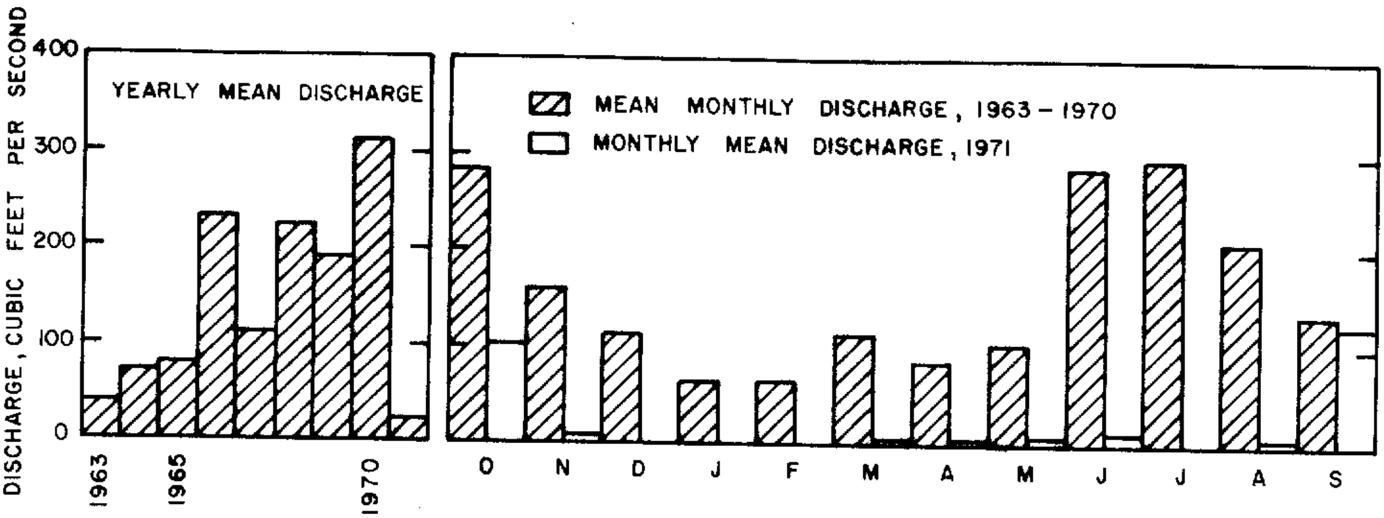


Figure 19.--Discharge and stage hydrographs for Hillsboro Canal near Deerfield Beach for the 1971 water year and 1940-71 water years.

Pompano Canal (C-14) and Cypress Creek Canal

Pompano Canal (fig. 2) is a major canal extending 12 miles east from Levee 36 Canal at structure S-38 to Pompano Beach where it flows southeast 2 miles to the Intracoastal Waterway. Flow is generally eastward and is dependent upon releases from Conservation Area 2A at S-38 and inflow from lateral canals from the north along the canal. Three miles west of Pompano Beach, Pompano Canal is joined by Cypress Creek Canal where flow is either diverted to Cypress Creek Canal (fig. 2) or continues eastward in Pompano Canal. Flow in Cypress Creek Canal is regulated by controls S-37B and S-37A (fig. 2).

The mean discharge in Cypress Creek Canal for 1971 of 21.9 cfs was about half that for 1963, the previous low yearly mean discharge for 1963-70 (fig. 20). No flow occurred during several months in 1971. September and October were the only months in which discharge was significant. The stage at S-37A was held above 3.0 feet msl during most of the 1971 water year (fig. 21) to replenish the aquifer in the area of the Fort Lauderdale well field.



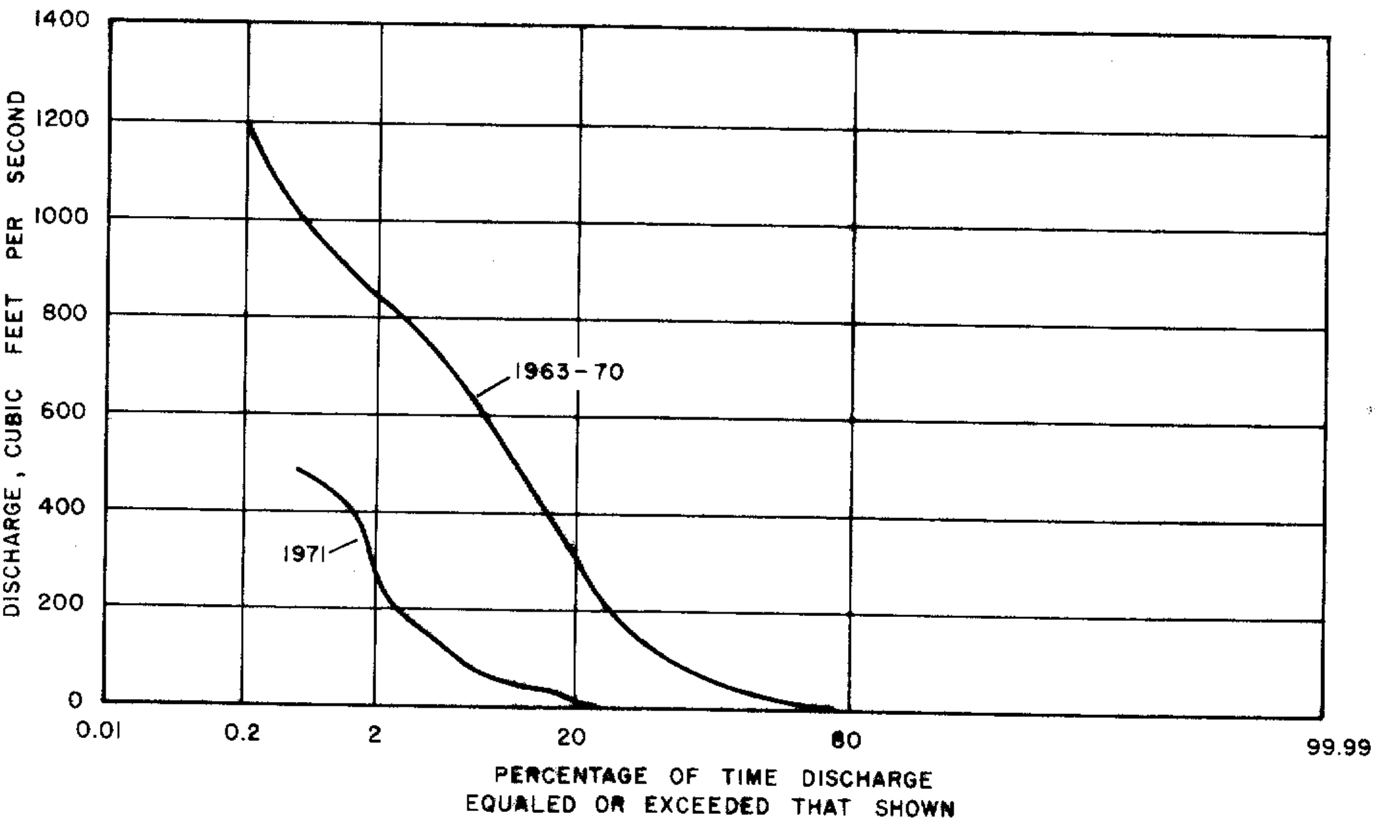


Figure 20 --Discharge data and flow-duration curves for Cypress Creek Canal at S-37A, near Pompano Beach.

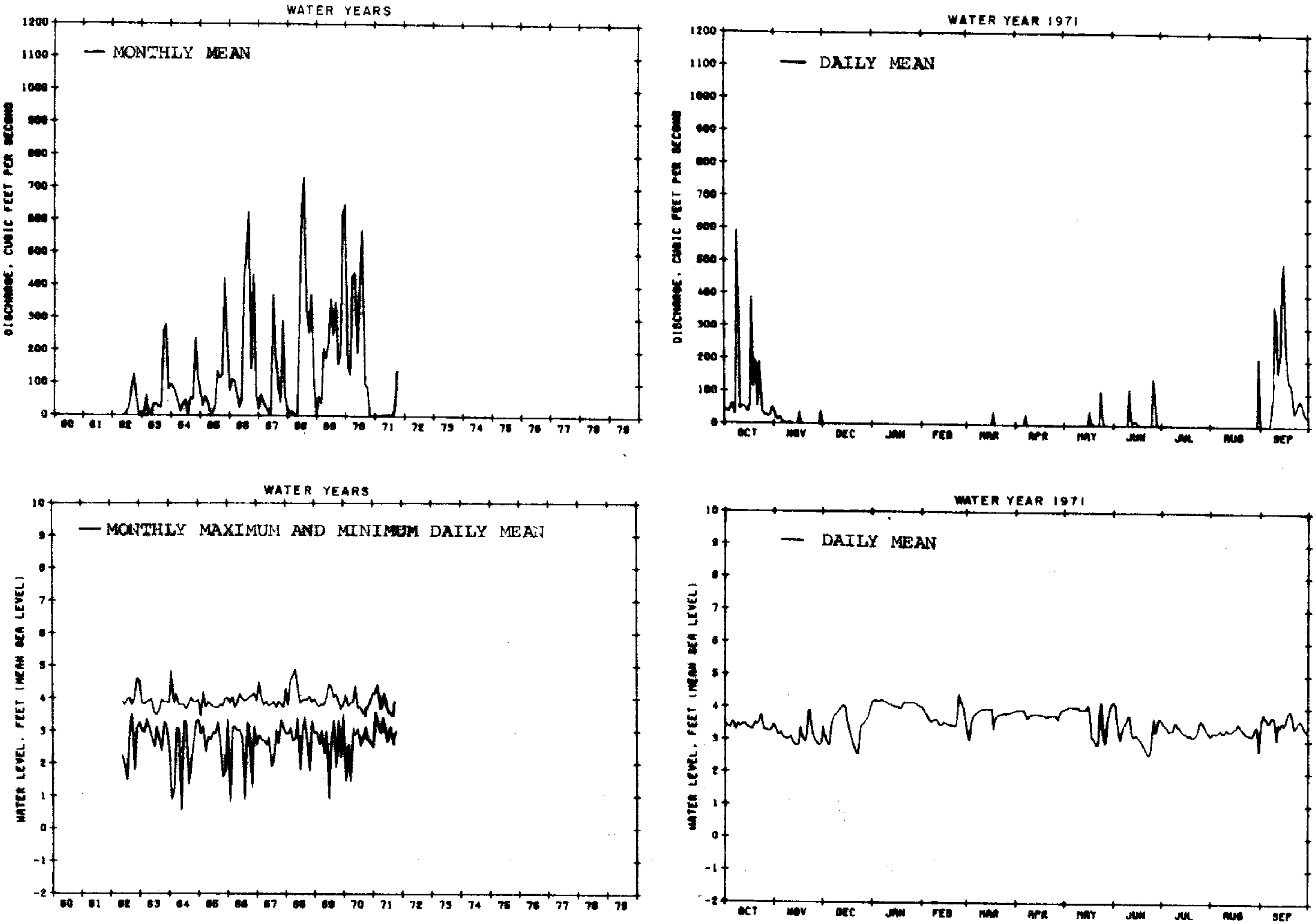


Figure 21 --Discharge and stage hydrographs for Cypress Creek Canal at S-37A near Pompano Beach for the 1971 water year and 1963-71 water years.

Middle River Canal (C-13)

Middle River Canal is a major canal that extends from C-42 Canal, near Conservation Area 2B, to the Intracoastal Waterway (fig. 2). Flow in the canal is regulated by controls in C-42 Canal and by control structure S-36, 1.5 miles east of U.S. Highway 441. Flow downstream of the control is affected by tidal fluctuations. A by-pass feeder canal is connected to the north side of the Middle River Canal 1 mile west of S-36. The feeder canal flows northward for 1 mile thence eastward for about 1.5 miles by means of connected borrow pits. The canal was constructed to replenish the aquifer in the Prospect well-field.

There was no flow through Middle River Canal in 1971 except for a few days during September. Consequently the average flow for the year was only 1.44 cfs, the lowest for the period 1962-71 (fig. 22). The stage at S-36 was held above 3.0 feet msl, except during the extreme dry months during the 1971 water year (fig. 23), to facilitate replenishment of the aquifer in the area of the Fort Lauderdale Prospect well field.

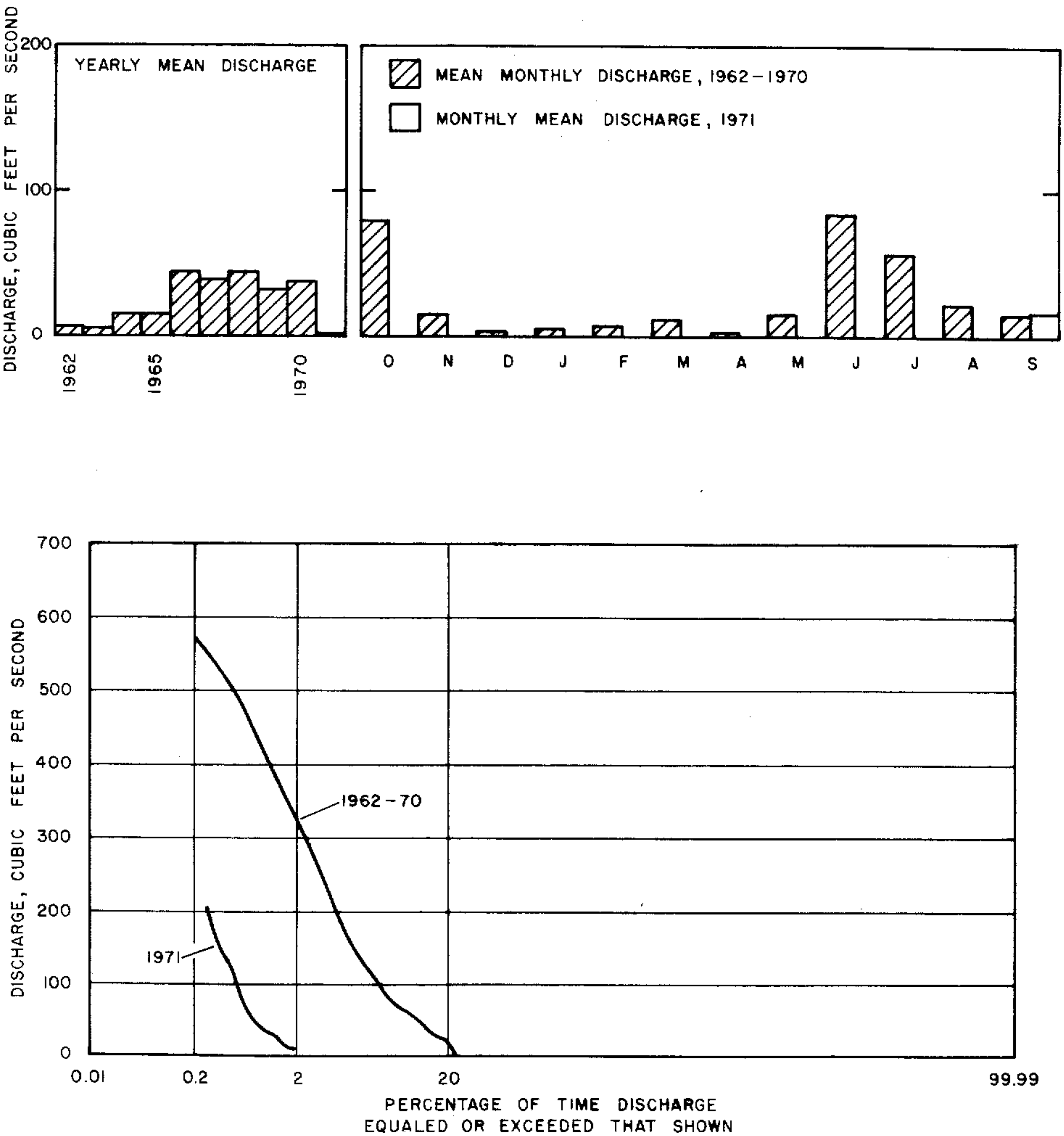


Figure 22 --Discharge data and flow-duration curves for Middle River Canal at S-36 near Fort Lauderdale.

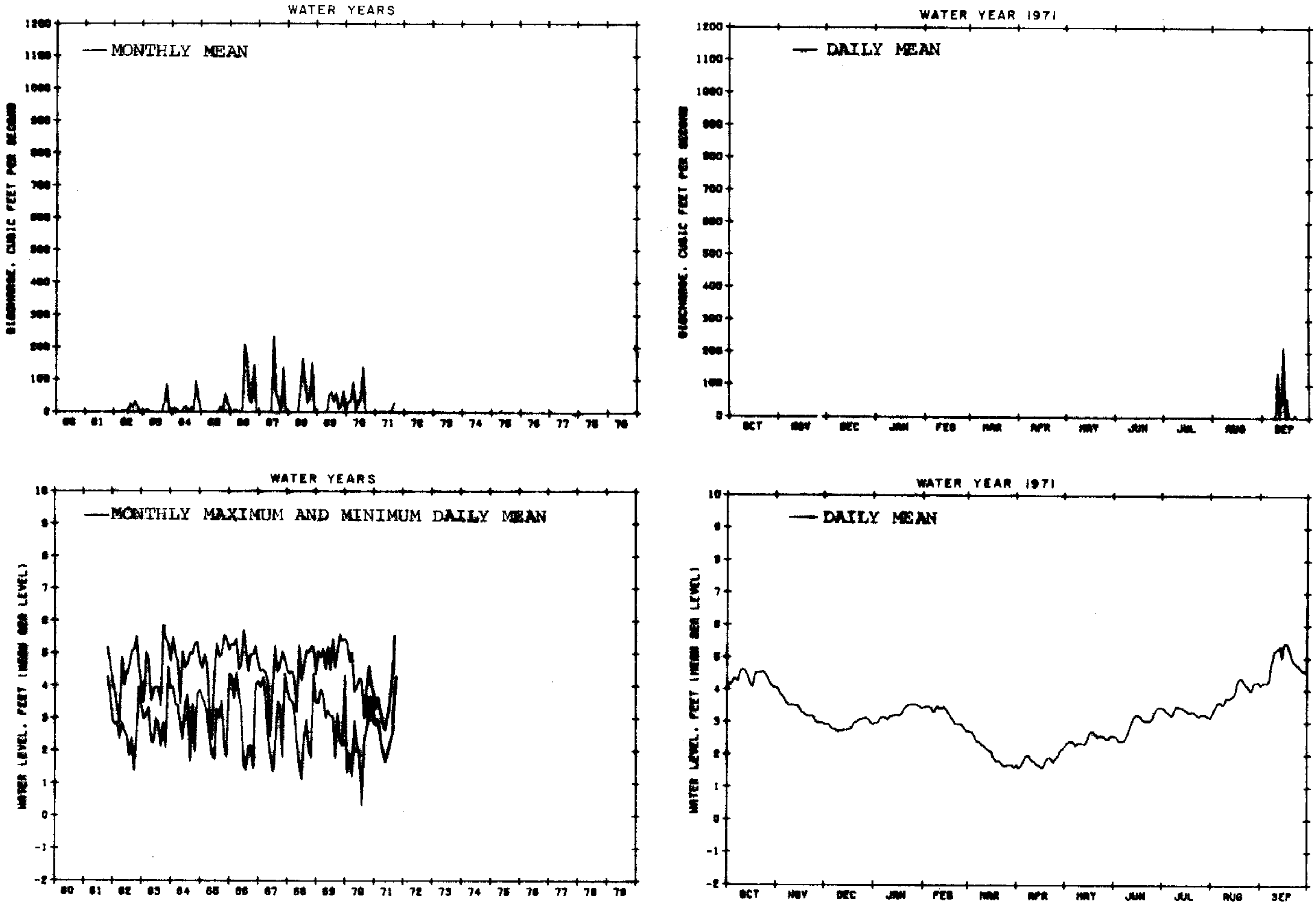


Figure 23 --Discharge and stage hydrographs for Middle River Canal at S-36 near Fort Lauderdale for the 1971 water year and 1962-71 water years.

Plantation Canal (C-12)

Plantation Canal extends east from Holloway Canal (fig. 2) to the North Fork New River. Flow in the canal is regulated by S-33, 0.5 mile east of U.S. 441. Seaward flow in the canal is generally low because the area drained by the canal is small and there is no interconnecting canal to provide flow from another source. During long dry periods this lack of flow has caused effluent wastes to concentrate and stagnant conditions to develop.

The mean discharge for 1971 at S-33 was 0.99 cfs which was record low for the period 1963-71 (fig. 24). The previous record low was 9 cfs, the record high only 40 cfs. In 1971, daily flow was zero except for 18 days; 1 day in March, 2 days in August, and 15 days in September. Therefore, the duration curve for 1971 does not follow the shape of the curve for previous years of record. The stage at S-33 was held above 3.0 feet msl during most of the 1971 water year (fig. 25) to prevent salt water encroachment.

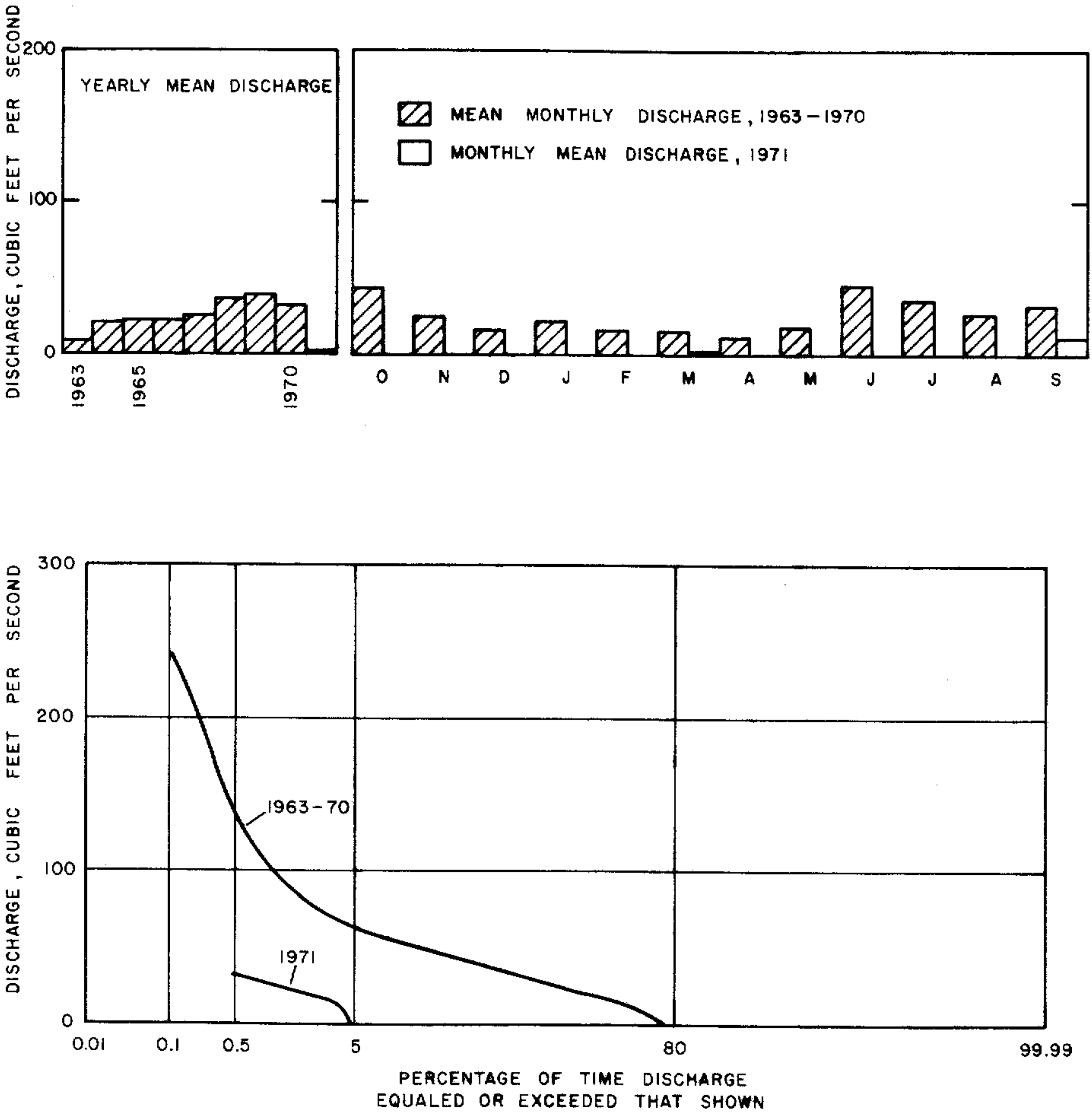


Figure 24 --Discharge data and flow-duration curves for Plantation Road Canal at S-33, near Fort Lauderdale.

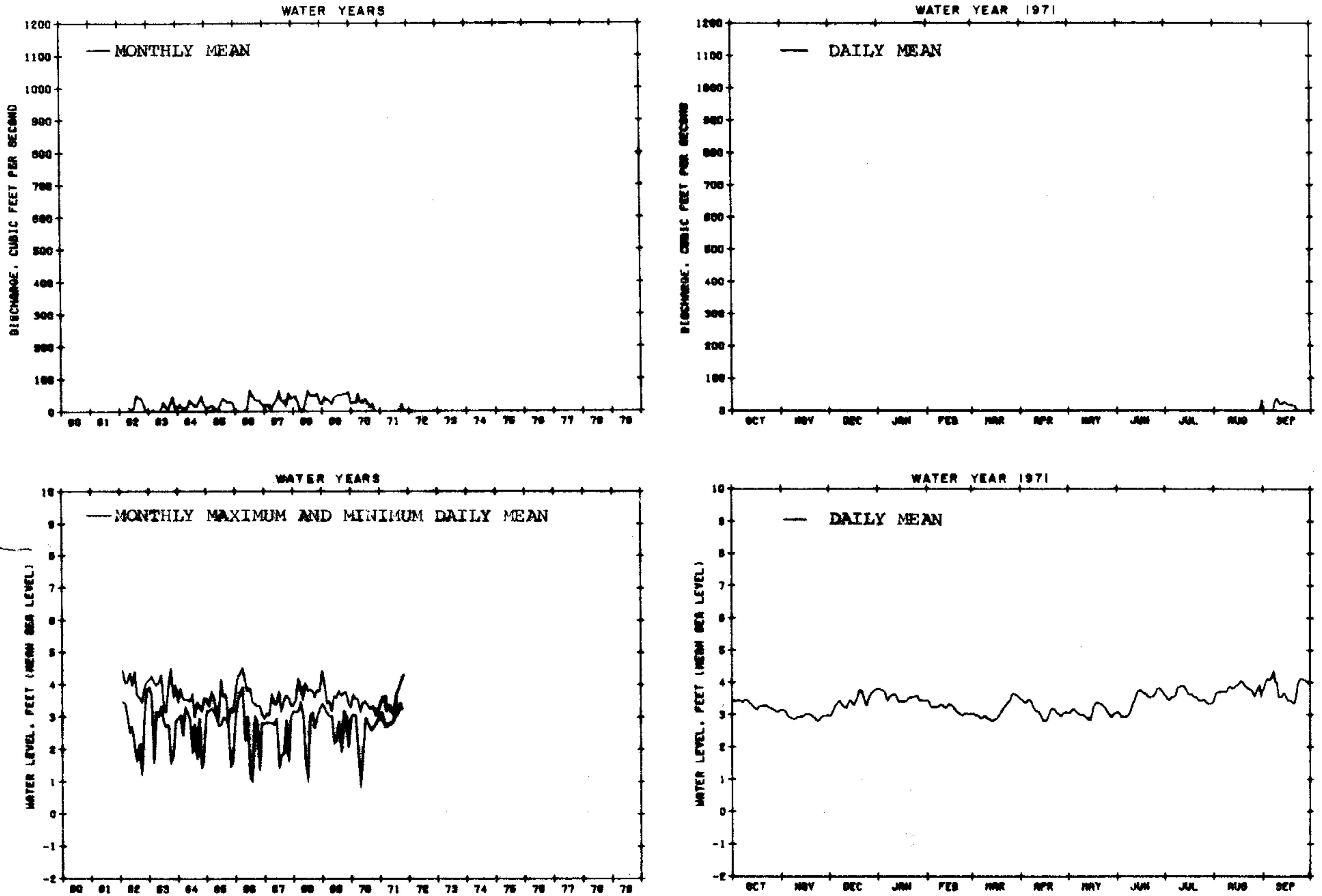


Figure 25 --Discharge and stage hydrographs for Plantation Road Canal at S-33, near Fort Lauderdale for the 1971 water year and 1962-71 water years.

North New River Canal

North New River Canal (fig. 1) is one of the major canals in the FCD network. The canal is 60 miles long, extending from the southeastern tip of Lake Okeechobee, south 30 miles to pump station S-7. From pump station S-7, the canal extends south through the western boundary of Conservation Area 2A to control S-34 where flow is controlled by manually operated head gates. Inside Area 2A the canal is divided into two segments, the upper of which is cut off from the lower by levees. South of S-34 the canal turns east and extends 14 miles to the Sewell Lock and Dam and then to the ocean.

The mean discharge at the Sewell Lock and Dam was 60 cfs for 1971, the lowest yearly mean discharge for the 30-year period, 1941-71 (fig. 26). There was no flow during December-May except leakage through the locks estimated at 15 cfs. The flow duration curves of figure 26 indicate that 10 percent of the time, discharge equalled or exceeded 200 cfs in 1971 and 725 cfs during 1962-70. The stage at the Sewell Lock and Dam was held above 3.0 feet msl during the 1971 water year (fig. 27) to replenish the aquifer and to prevent salt-water encroachment.

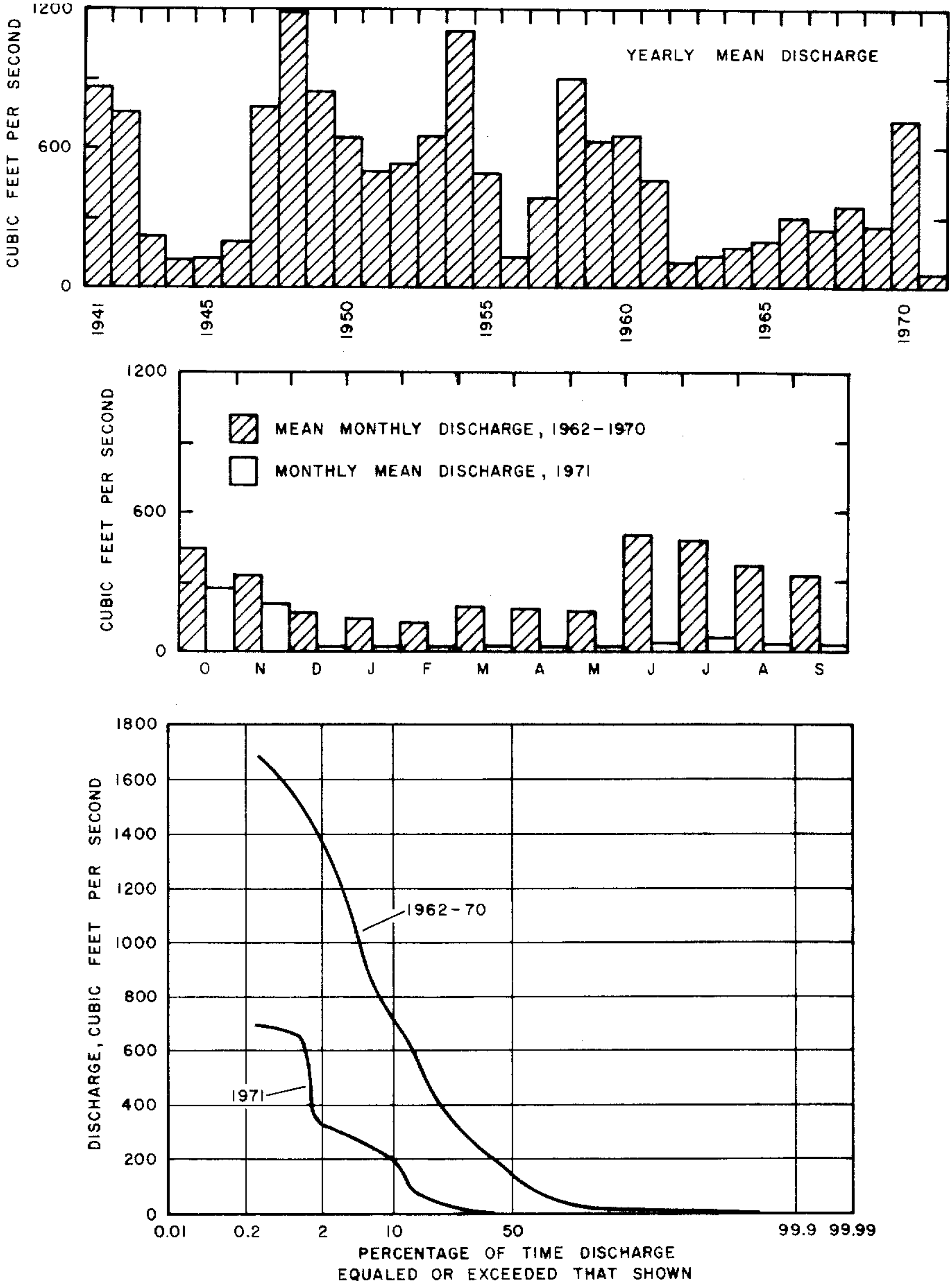


Figure 26 --Discharge data and flow-duration curves for North New River Canal near Fort Lauderdale (lock and dam).

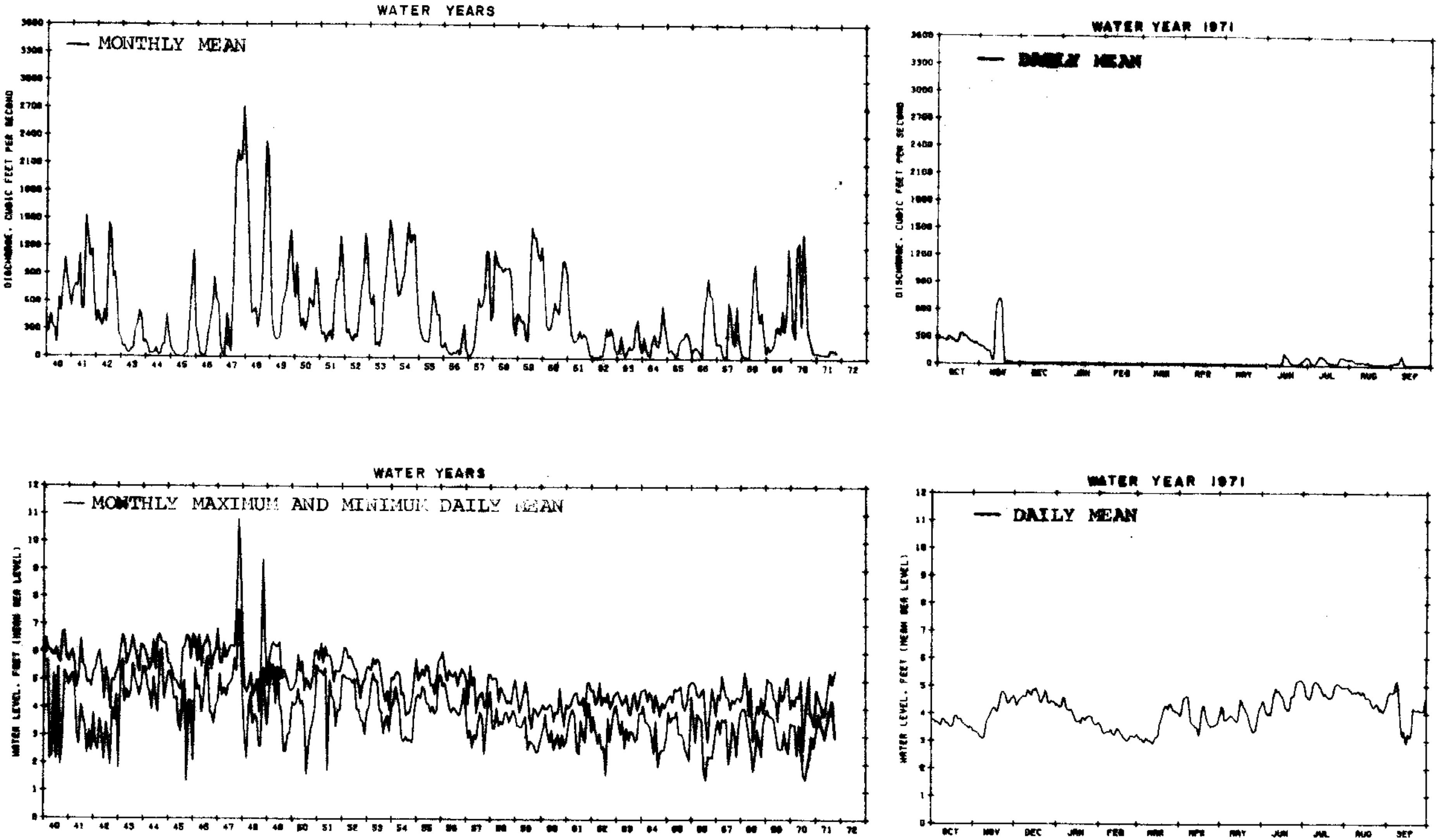


Figure 27 --Discharge and stage hydrographs for North New River Canal near Fort Lauderdale (lock and dam) for the 1971 water year and 1940-71 water years.

South New River Canal (C-11)

South New River Canal, a major canal, begins at the Miami Canal (fig. 1) in Conservation Area 3A in western Broward County and extends east about 5 miles to the eastern boundary of Area 3A at pump station S-9 (fig. 1). The canal extends east from S-9 18 miles until it divides into the Dania Cut-off Canal and the South Fork New River. Pump station S-9 removes flood water from the South New River Canal east of S-9 and discharges it into Conservation Area 3A. Control station S-13A, 4.4 miles west of U.S. Highway 441, and S-13, a pump station with a sluice gate control at U.S. Highway 441, regulate flow in the east part of the canal.

The mean discharge at S-13 for 1971 was 59.5 cfs, 50 percent of the record low yearly mean discharge (1962) for 1958-70 (fig. 28). Flow was slightly below average in October and November, but extremely low during the succeeding 5 months. The flow was zero during most of March and April. Flow-duration curves (fig. 28) indicate that 40 percent of the time flow equalled or exceeded 40 cfs in 1971, and 210 cfs for 1962-70.

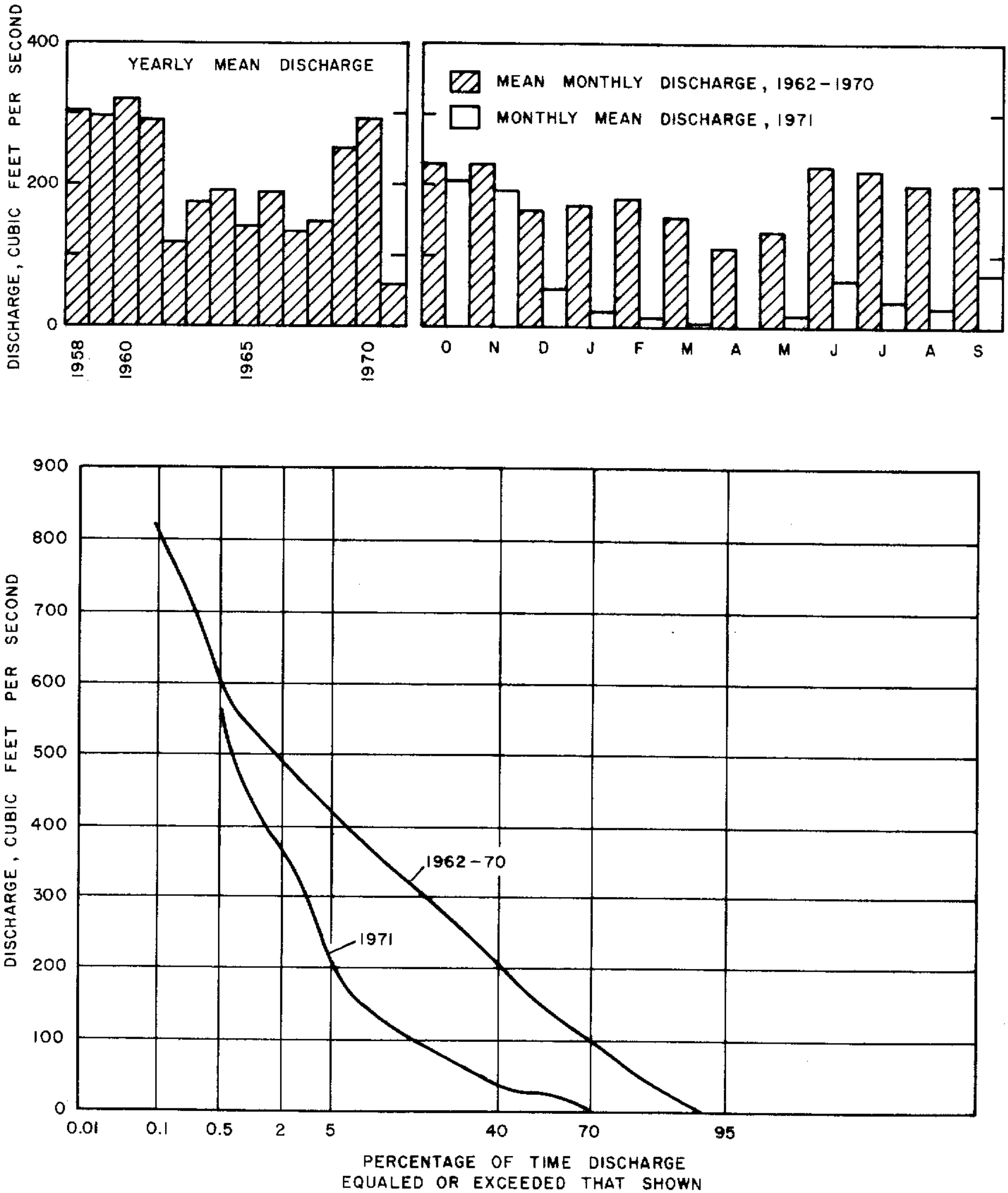


Figure 28.--Discharge data and flow-duration curves for South New River Canal at S-13, near Davie.

The stage at S-13 on the easternmost reach of the canal averaged about 1.8 feet above msl (fig. 29) during the 1971 water year with little variation in the mean daily stages from February - September 1972. Water levels maintained at S-13 are generally lower than those at other salinity control structures in the county because the canal drains a very low flood-prone area.

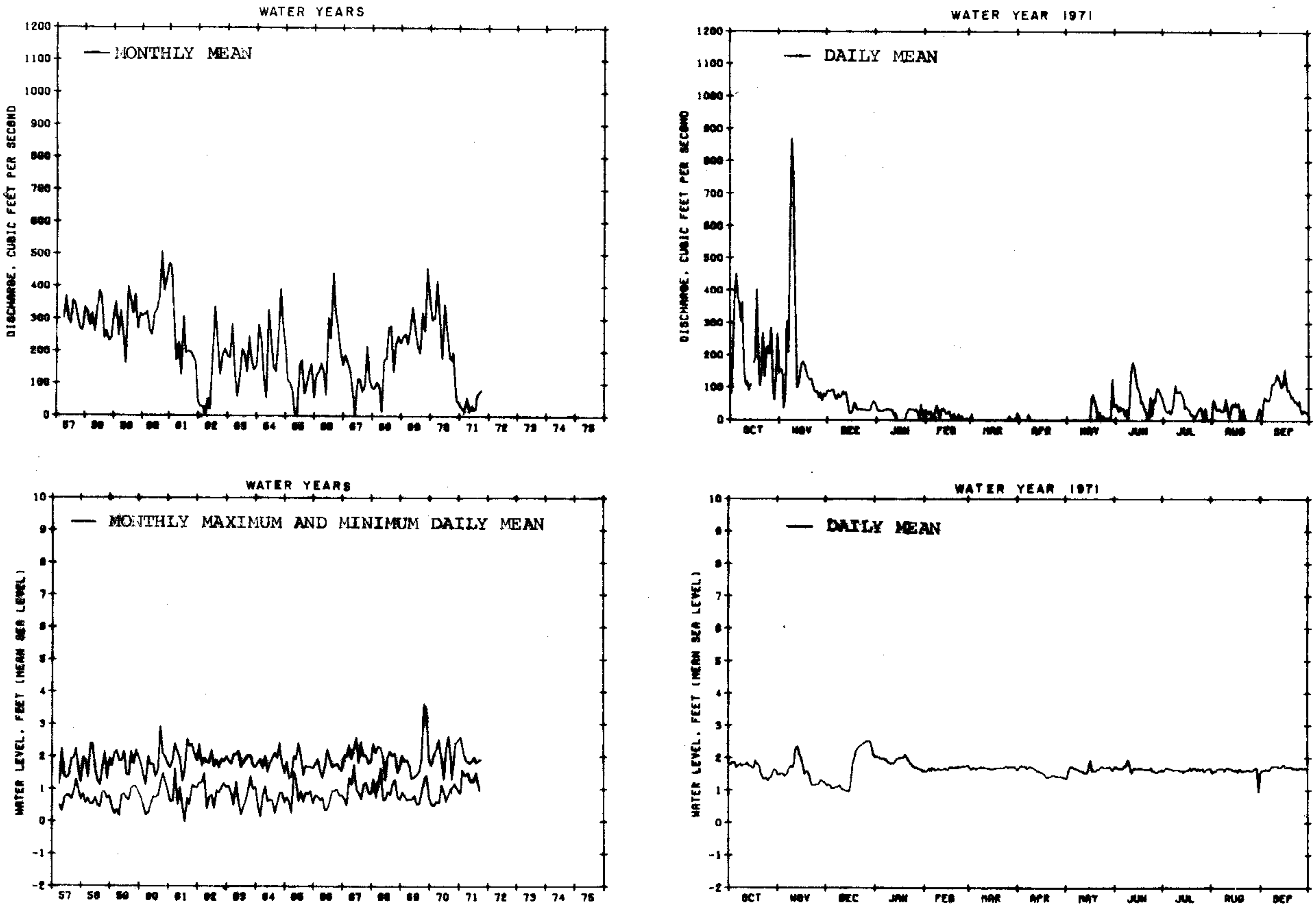


Figure 29.--Discharge and stage hydrographs for South New River Canal at S-13, near Davie for the 1971 water year and 1957-71 water years.

Snake Creek Canal (C-9)

Snake Creek Canal is the primary drainage channel for the coastal area along the Dade County - Broward County boundary (fig. 2). The main channel extends eastward from the perimeter canal on the east side of Conservation Area 3B to the coast. Although most of the lower reach of the canal is in Dade County it forms the southern hydraulic boundary for Broward County. Flow in the canal is regulated by gated culverts at S-30, 0.75 mile east of the Area 3B boundary, and submerged sluice gates at S-29, just east of U.S. Highway 1. Flow in the canal is maintained chiefly by ground-water inflow, but water can be diverted from the conservation areas by manipulation of controls. Snake Creek Canal also has a north-fork about 8 miles east of S-30 that extends to North New River Canal (fig. 2).

The mean discharge of 206 cfs (fig. 30) for 1971 at Northwest 67th Avenue was slightly higher than the record low of 189 cfs in 1963. Monthly mean discharges were below the 1963-70 mean monthly averages throughout the 1971 year, and were less than half of the 1963-70 mean monthly average during February through May. The stage was held above 2.0 feet msl during most of the 1971 water year with little variation in the mean daily stage (fig. 31).

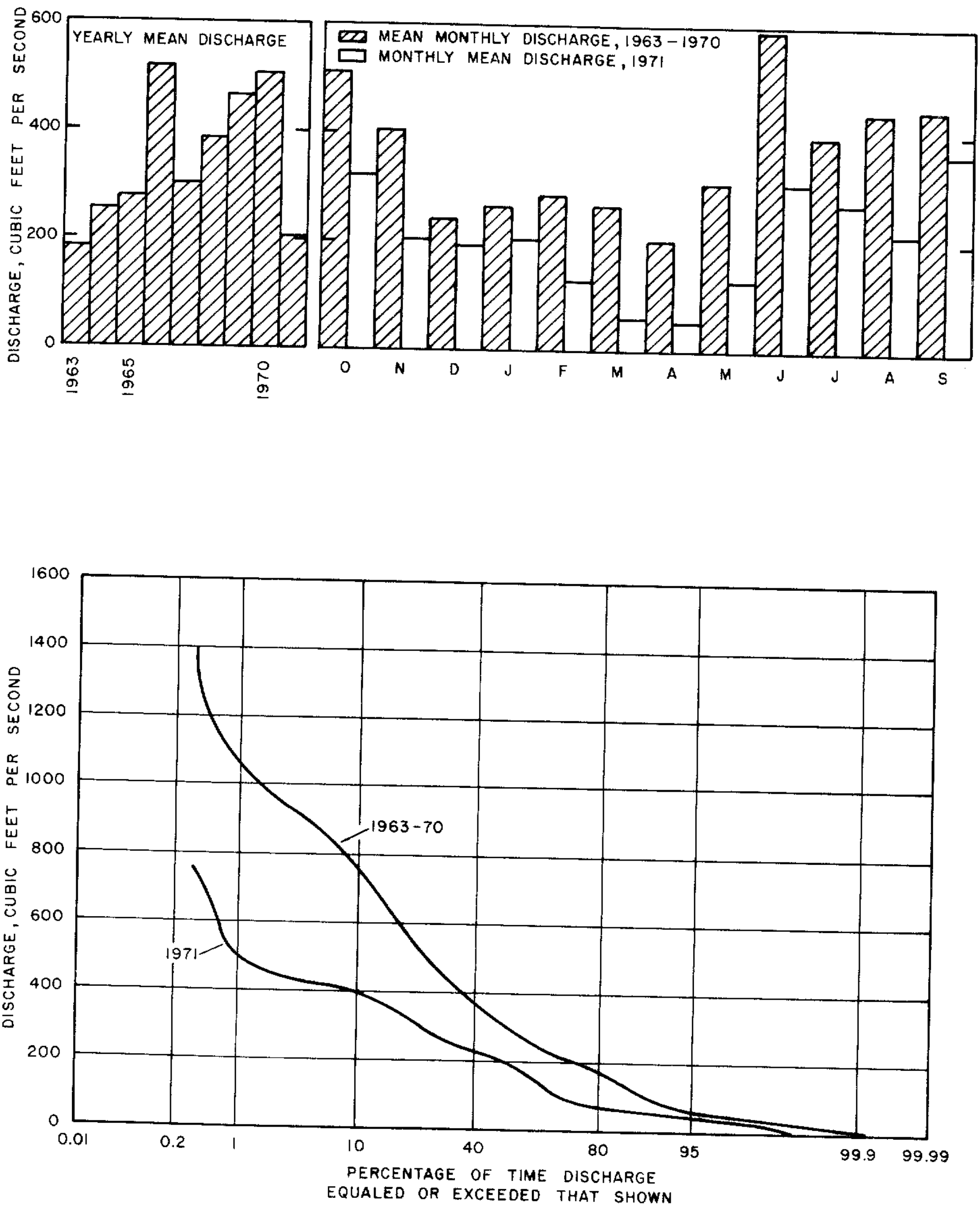


Figure 30 --Discharge data and flow-duration curves for Snake Creek Canal at Northwest 67th Avenue near Hialeah.

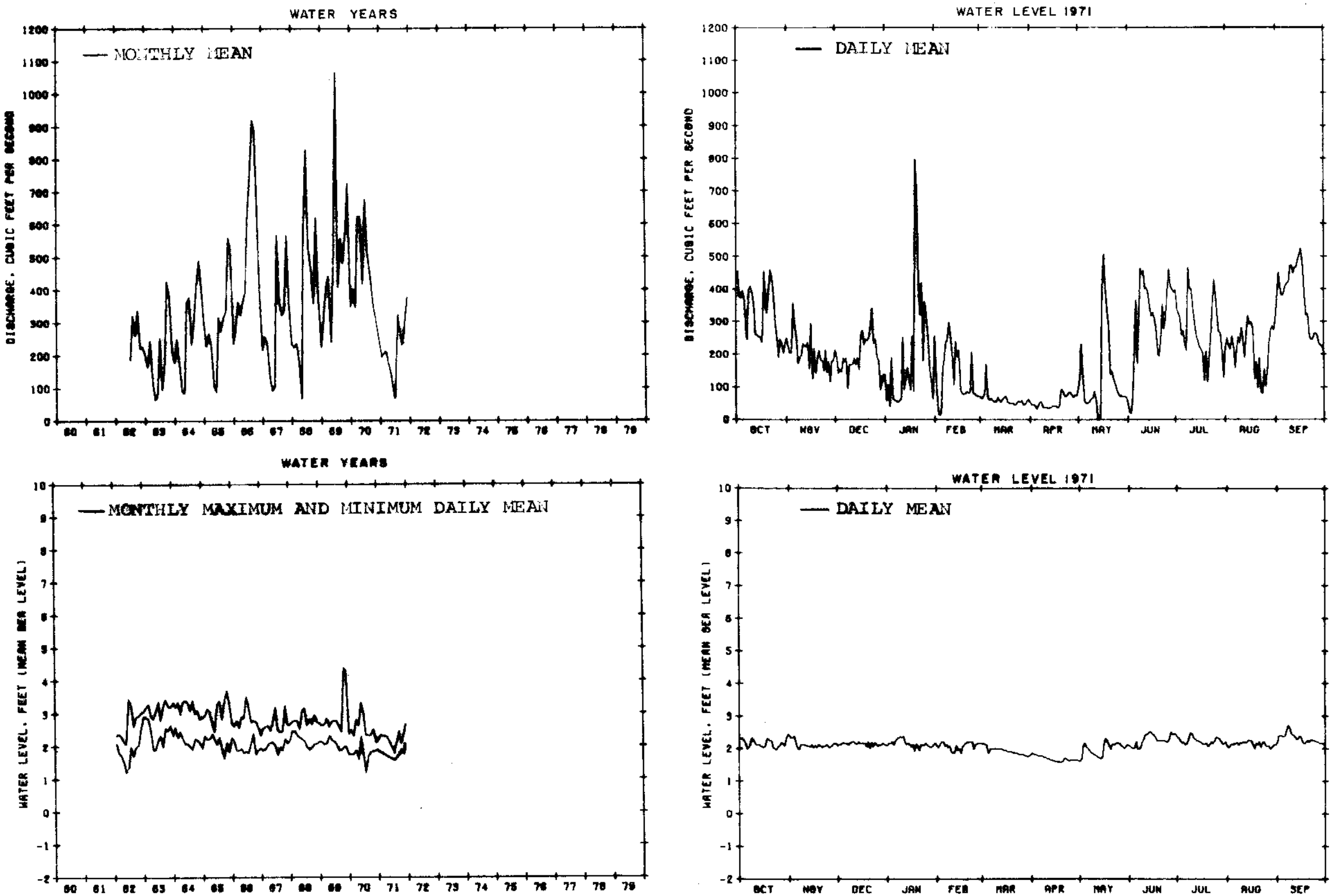


Figure 31 --Discharge and stage hydrographs for Snake Creek Canal at Northwest 67th Avenue, near Hialeah for the 1971 water year and 1962-71 water years.

The mean discharge for 1971 at S-29 was 207 cfs (fig. 32), slightly higher than the record low of 197 cfs in 1962. Although the mean discharge at Northwest 67th Avenue and S-29 for 1971 were about the same, distribution of monthly flows were quite different during the dry months of January - May. Daily mean discharge at S-29 is generally 50-100 cfs higher than at Northwest 67th Avenue. During extremely dry years, the flows at both stations are about the same because S-29 remains closed through the dry months to maintain high levels in the canal to recharge the aquifer in the coastal areas adjacent to the canal. The stage at S-29 was held above 1.0 foot msl during the 1971 water year (averaged about 1.8 feet msl) with little variation in the daily mean stage (fig. 33). Discharge at S-29 is regulated to mainatin optimum stages in flood prone areas along the upstream reaches of the canal during the wet season and in the canal to replenish the aquifer and prevent salt-water encroachment in the coastal area during the dry season.

Flow in Snake Creek Canal in 1971, was much greater than in any other canal in Broward County. The 1971 duration curves (figs. 30 and 32) for both stations conformed to the 1962-70 curves better than any of the 1971 curves for any other canal to their respective 1962-70 curves.

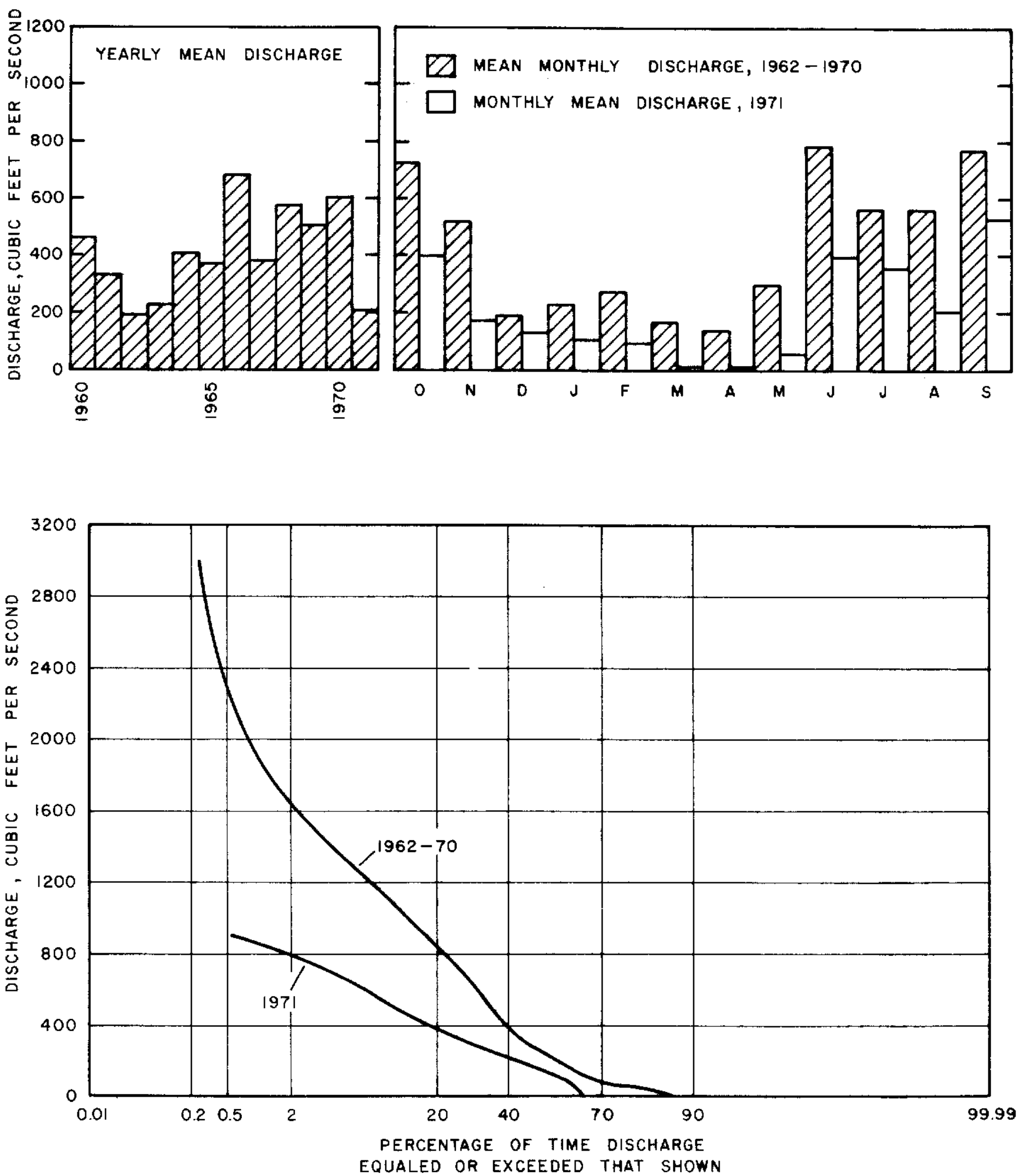


Figure 32 --Discharge data and flow-duration curves for Snake Creek Canal at S-29, at North Miami Beach.

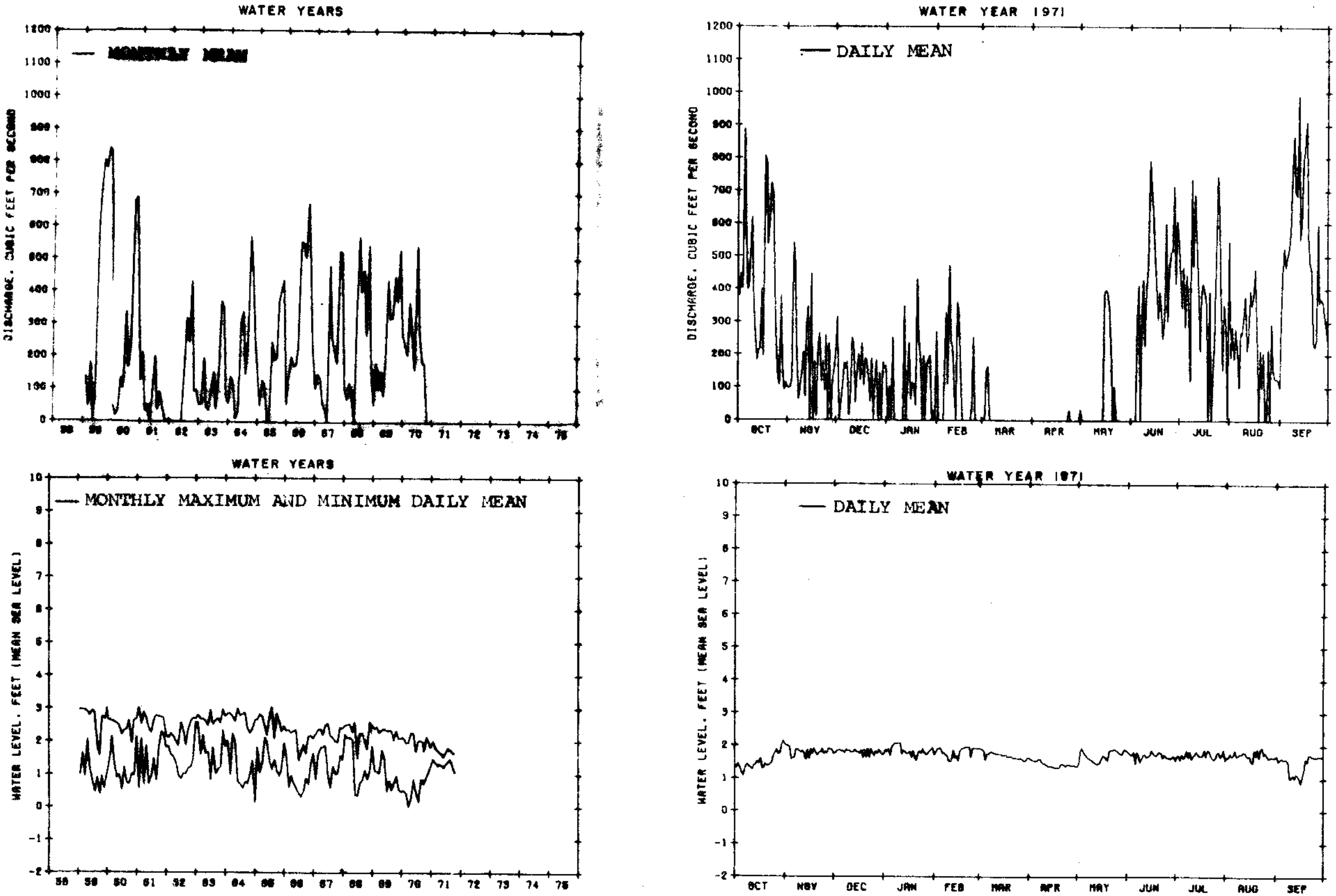


Figure 33.--Discharge and stage hydrographs for Snake Creek Canal at S-29, at North Miami Beach for the 1971 water year and 1959-71 water years.

Intracoastal Waterway

The Intracoastal Waterway parallels the coast in Broward County (fig. 2) and is separated from the ocean by a narrow offshore bar. Seaward flow from all of the canals in Broward County discharges into the waterway, then to the ocean through one of the several narrow inlets in Palm Beach, Broward, and Dade Counties.

Water levels in the Intracoastal Waterway are affected by flow from the management system chiefly when discharge is high. The mean monthly low-water levels in the waterway during the 1971 water year (figs. 33 and 34) were about the same as the levels during the 1968-70 water years even through an extreme drought occurred during 1971. The mean high-water levels (monthly) were much lower at all stations during 1971.

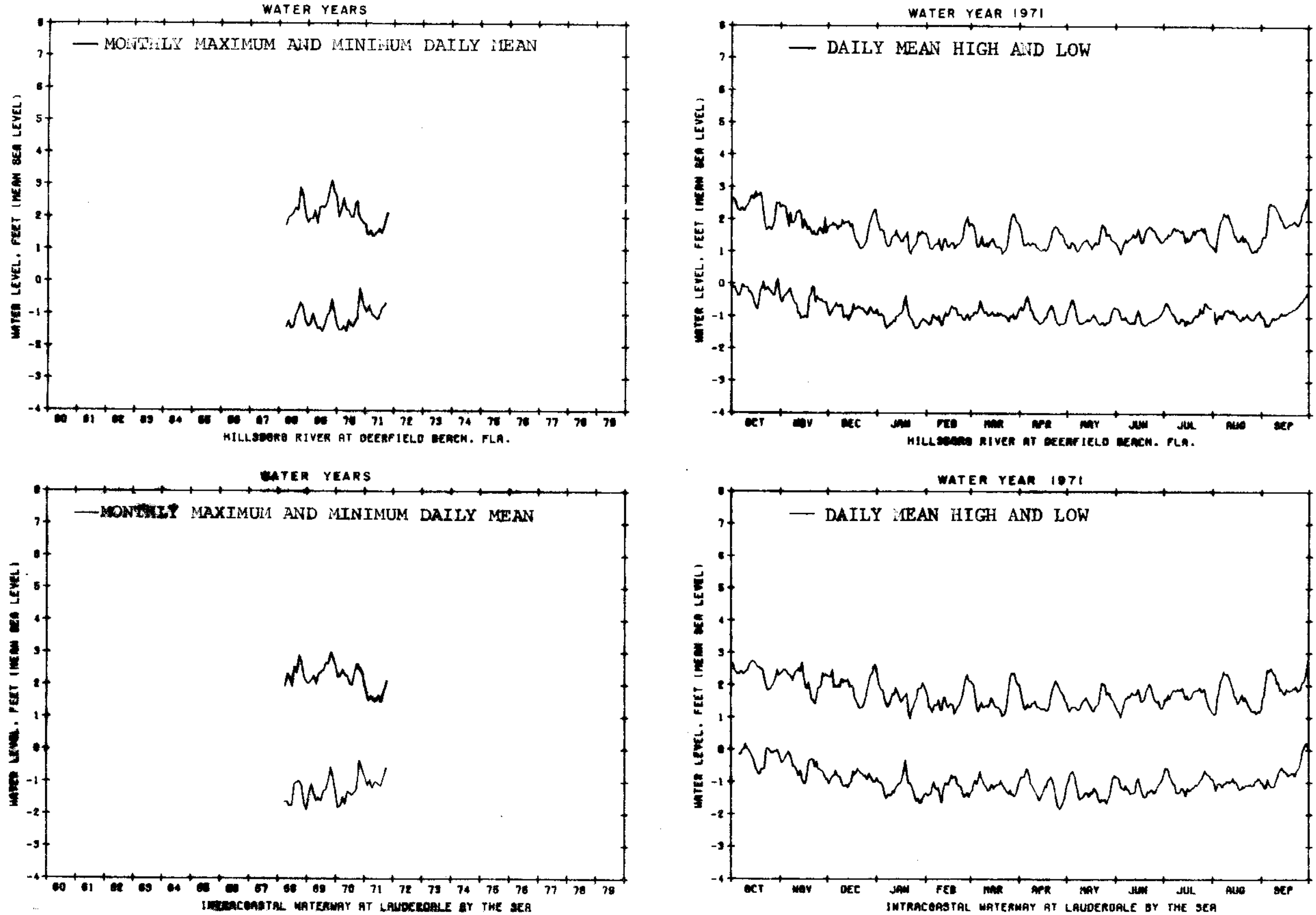


Figure 34 --Hydrographs of tidal fluctuations in Hillsboro River at Deerfield Beach and in the Intracoastal Waterway at Lauderdale-by-the-Sea, for the 1971 water year and 1968-71 water years.

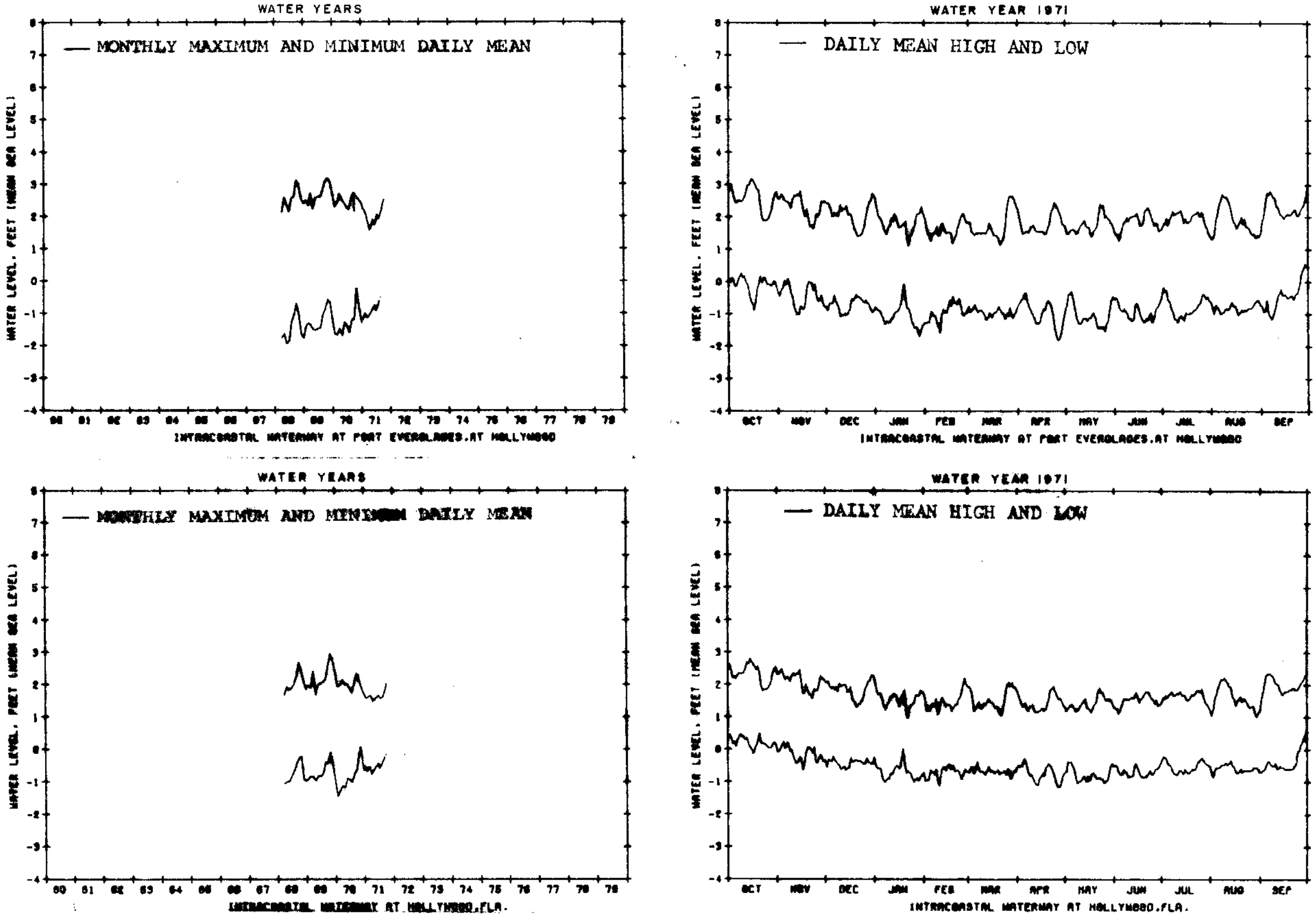


Figure 35 --Hydrographs of tidal fluctuations in the Intracoastal Waterway at Port Everglades, at Hollywood and at Hollywood, for the 1971 water year and the 1968-71 water years.

WATER QUALITY

Ground water in Broward County can be used for most purposes without treatment and can be easily treated to meet standards recommended by the U.S. Public Health Service 1962 for public supply The water is hard because of limestone dissolved from the Biscayne aquifer and it contains objectionable quantities of iron in some areas.

The quality of untreated or raw surface waters in Broward County generally meets criteria for most uses, but the quality is highly variable and thus, the water is difficult to treat. The chief threat to surface-water quality in urban areas is manmade contamination. However, the levels of contaminants are generally low except in canals that receive large quantities of sewage effluent and have low flow.

In general, the concentrations of the natural constituents in surface-waters in Broward County are within the limits established by Florida State Water Standards (Grantham and Sherwood, 1968). Table 2 shows the range of some of the most significant parameters in determining water quality in south Florida. Although not considered to be a major factor, these waters are generally high in iron. Water with calcium carbonate from 120 to 180 mg/l is considered to be hard and over 180 mg/l very hard and water with iron content higher than 0.3 mg/l will cause staining (McKee and Wolf, 1963). The iron content at the eight sites in table 2, exceeded the 0.3 mg/l

Table 2.--Ranges of water-quality parameters at selected sites in Broward County canals, 1971 water year.

(Results in milligrams per liter except where noted)

	Site 1[6]	Site 7	Site 10	Site 11
Specific Conductance [1]	620 - 832	524 - 610	634 - 840	590 - 620
pH (units	6.9 - 8.4	6.7 - 8.1	8.0 - 8.5	6.7 - 7.8
Color[2]	50 - 70	30 - 45	45 - 60	45
Dissolved Solids	392 - 534	386 - 413	406 - 482	407[5]
Iron (Fe)	0.10 - 0.15	0.02 - 0.06	0.03 - 0.04	0.03 - 0.10
Bicarbonate (HCO_3)	260 - 314	214 - 274	232 - 296	242 - 262
Hardness as $CaCO_3$ (Calcium Magnesium)	230 - 290	245 - 250	231 - 280	250[5]
Non Carbonate	27 - 41	20 - 38	25 - 38	50[5]
Chloride (Cl)	62 - 100	48 - 51	64 - 110	39 - 58
Phosphorus (P) as PO_4	0.05 - 0.38	0.09 - 0.43	0.55 - 0.87	1.6 - 5.4
Nitrogen (N) as				
NO_3	0.00 - 1.2	.3 - 1.8	.0 - 0.7	1.2 - 14
NO_2	.00 - 0.14	.02 - 0.05	.01 - 0.05	0.17 - 2.2
NH_4	.08 - .44	.03 - .09	.01 - .58	.19 - 0.58
Organic	.50 - 1.0	.85 - 1.1	.40 - 1.2	.78 - 1.6
Detergents (MBAS)	.04 - 0.07	.01 - 0.05	.05 - .08	.03 - 0.09
B.O.D.	.8 - 2.1	1.4[5]	.4 - 2.4	1.6 - 6.5
Coliform [3]				
Total	30 - 5,200	1,000- 1,550	100 - 2,850	140 - 12,000
Fecal	0 - 110	20[5]	5[5]	10 - 50
DDT Family [4]				
Water	0.00	0.00	0.00 - 0.02	0.00 - 0.01
Sediment	0.80 - 35	7.5 - 246		7.5[5]
Silvex [4]				
Water	0.01 - 0.80	0.00 - 0.05	0.03 - 0.09	0.00 - 0.03
Sediment	0.00	0.5[5]		

1 micromhos at 25C°
2 platinum - cobalt scale
3 colonies per 100 milliters
4 micrograms per liter (water) or kilogram (sediment)
5 only determination for year
6 for location of sampling sites see figure 3.

5/23/73

Table 2.--(Cont.) Ranges of water-quality parameters at selected sites in Broward County canals, 1971 water year
(Results in milligrams per liter except where noted)

	Site 15 6/	Site 21	Site 23	Site 43
Specific Conductance 1/	460 - 750	630 - 720	590 - 650	660 - 670
pH (units	6.7 - 7.6	7.4 - 8.1	7.2 - 8.1	7.2 - 8.2
Color 2/	40 - 55	30 - 60	70 - 100	40 - 50
Dissolved Solids	286 - 459	380 - 428	396 - 417	388 - 397
Iron (Fe)	0.05 - 0.20	0.04 - 0.37	0.08 - 0.18	0.17 - 0.26
Bicarbonate (HCO_3)	126 - 193	196 - 284	280 - 305	292 - 296
Hardness as $CaCO_3$ (Calcium Magnesium)	140 - 170	207 - 250	250 - 270	240 - 250
Non Carbonate	0 - 39	0 - 49	17 - 27	5 - 11
Chloride (Cl)	41 - 100	66 - 88	50 - 68	68 - 76
Phosphorus (P) as PO_4	10 - 30	0.03 - 0.06	0.27 - 0.44	0.02 - 0.06
Nitrogen (N) as				
NO_3	0.00 - 0.20	.10 - 1.6	.3 - 1.6	.2 - 0.7
NO_2	.01 - 0.15	101. - 0.09	.02 - 0.20	.01 - 0.04
NH_4	2.2 -29	.02 - 0.62	.42 - 0.89	.10 - 0.36
Organic	.01 -20	.42 - 2.2	1.0 - 2.4	.56 - 2.1
Detergents (MBAS)	.30 - 0.32	.03 - 0.07	.00 - 0.10	.03 - 0.05
B.O.D.	6.6 - 7.9	.4 - 1.3	1.1 - 2.5	.4 - 1.0
Coliform 3/				
Total	30,000 -300,000	240- 4,000	260 -53,000	450- 1,400
Fecal	900 - 20,000	10- 30	40 - 75	0- 90
DDT Family 4/				
Water	0.01 - 0.03	0.00 - 0.02	0.00	0.00
Sediment	24 - 152	.00 -49	2.7 5/	0.00 - 3.6
Silvex 4/				
Water	0.01 - 0.28	.00 - 0.05	0.1 5/	0.00 - 0.04
Sediment	15 5/	.00 - 0.4	0.00	0.00

1 micromhos at 25C°
2 platinum - cobalt scale
3 colonies per 100 milliters
4 micrograms per liter (water) or kilogram (sediment)
5 only determination for year
6 for location of sampling sites see figure 3.

limit only at site 21, but the calcium carbonate greatly exceeds 120 mg/l at every site.

Typical indicators of manmade contaminants are nutrients, detergents, bacteria and pesticides. Nutrients include the nitrogen family and phosphorus. Bacteriological parameters include total and fecal coliform. Pesticides include all the insecticides and herbicides.

The DDT family (DDT, DDD, and DDE) is generally the highest level of insecticides and silvex the highest level of herbicides found in Broward County canals. Concentrations are generally much higher in the sediments (table 2), although, concentrations in both the water and sediments are generally within a safe range.

High levels of nitrogen (nitrite, nitrate, ammonia, and organic nitrogen) and phosphorus can usually be attributed to sewage outfalls and/or agricultural fertilizers. Nutrients in the agricultural areas are not abnormally high and the one canal that shows high values for nutrients is located in an urban area and receives considerable flow from sewage outfalls.

Detergents, MBAS (methylene blue active substance), are found at times in all the canals. This parameter reflects the household and industrial cleaners introduced into the canals by man.

The coliform group (total and fecal) is used as an indicator of contamination. Total coliforms live in soils, natural waters and in the intestines of warm blooded animals. Fecal coliforms are a better indicator than total since their presence in water indicates contamination derived from animal or human sources.

Surface Water Criteria for Public Water Supplies (FWPCA, 1968) lists 10,000 total coliforms per 100 ml (milliliters) and 2,000 fecal coliforms per 100 ml as permissible limits and less than 100 total coliforms per 100 ml and less than 20 fecal coliforms per 100 ml as desirable limits.

At sites 11 and 23 total coliform counts are sometimes above the permissible limits and at site 15, are always above (table 2). The fecal coliform counts were over the permissible limit only at site 15, above control S-33 in Plantation Canal. Flow in Plantation Canal is generally low because the area drained by the canal is small. During long dry periods this lack of flow has caused the concentration of effluent wastes and stagnant conditions.

DO concentration is measured in milligrams of oxygen per liter of water. Weather conditions, sunlight intensity, surface runoff, ground-water inflow, plant activity, and the decomposition of organic materials are constantly changing and affecting the liberation or utilization of oxygen by physical, chemical, or biological activities. As a result of these activities the DO content changes during each day and seasonally.

The DO content in Broward canals appears to be lowest in September - December after the rainy season when water levels and flow in the canals are high (fig. 36). The DO content appears to be highest in March - June, the dry season when canal flow is low.

Florida's Department of Pollution Control (FDPC) and the Federal Water Pollution Control Administration (FWPCA) have established criteria for DO content in waters intended to be used for recreation and the propagation and management of fish and wild life. The FDPC criterion states that the DO content shall not be artificially depressed below 4 mg/l unless background information indicates lower values under unpolluted conditions. The FWPCA criterion states that the DO content should remain above 5 mg/l daily; under extreme conditions the DO may range between 5 and 4 mg/l for short periods of time, provided that the water quality is favorable in all other respects.

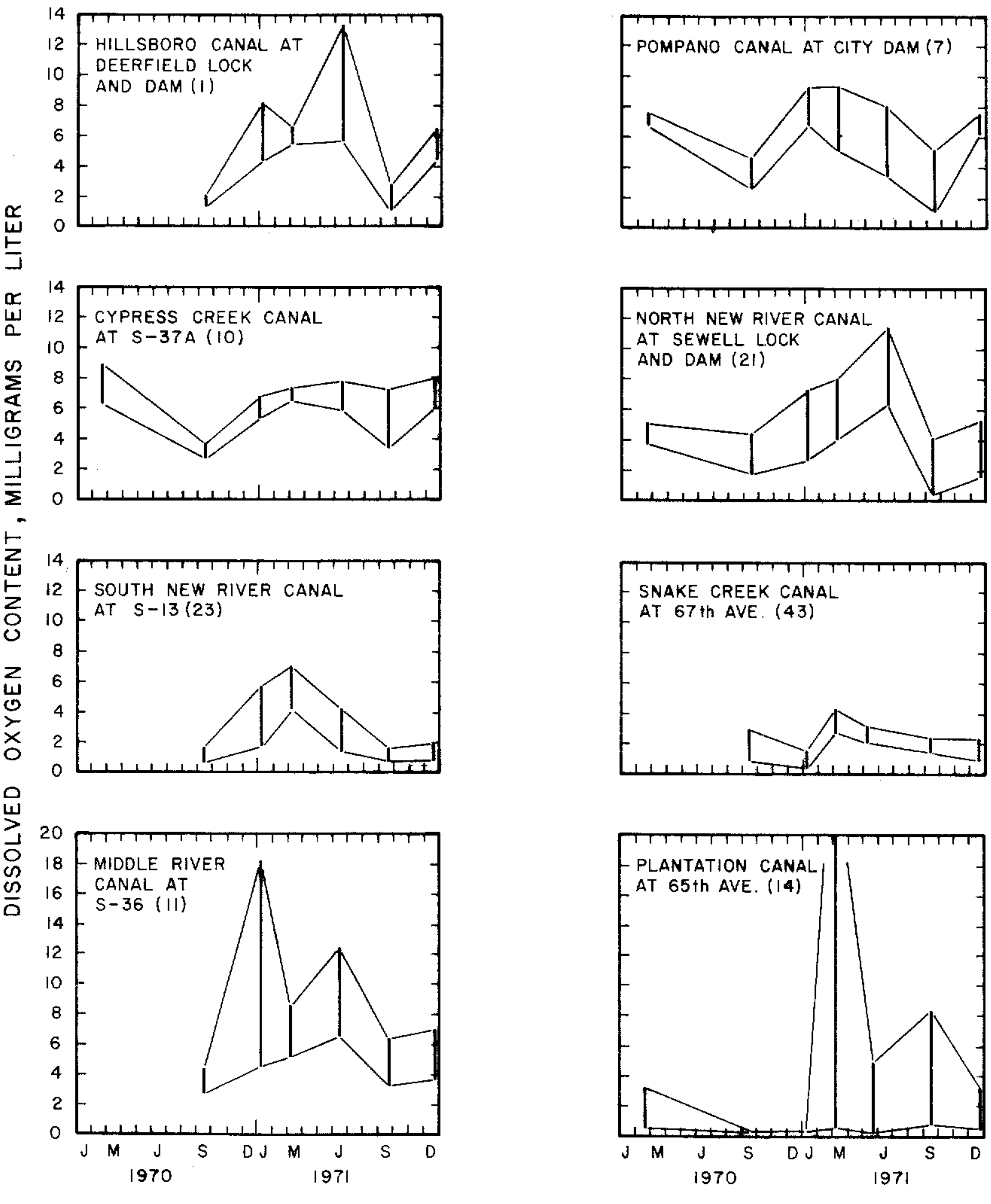


Figure 36.--Range of dissolved oxygen content for a 24-hour period at selected times and selected sites in Broward County.

SEA-WATER INTRUSION

Sea-water intrusion is a major threat to coastal fresh-water supplies in Broward County. This threat is a result of man's altering the surface-flow system, an alteration that began early in the century with the construction of deep drainage canals. The canals permitted sea water to flow inland during periods of low discharge and also lowered the water table below the level required to prevent the movement of sea water into the aquifer. Drawdown caused by heavy pumping from well fields along the coast has become a factor in salt-water intrusion in recent years. Ground-water levels are lowered as much as 5 feet below mean sea level in some well fields during the dry season.

Controls have been built on all major canals near the coast to halt upstream movement and to maintain high fresh-water heads to prevent intrusion into the aquifer. However, the controls are 2 to 5 miles inland from the Intracoastal Waterway, thus allowing sea water to move inland when water levels and discharge in the canals is low. The chloride content of water downstream from most of the controls in Broward County varies from 80 mg/l in some canals to 18,500 mg/l, depending on whether low-water or high-water conditions prevail (fig. 37).

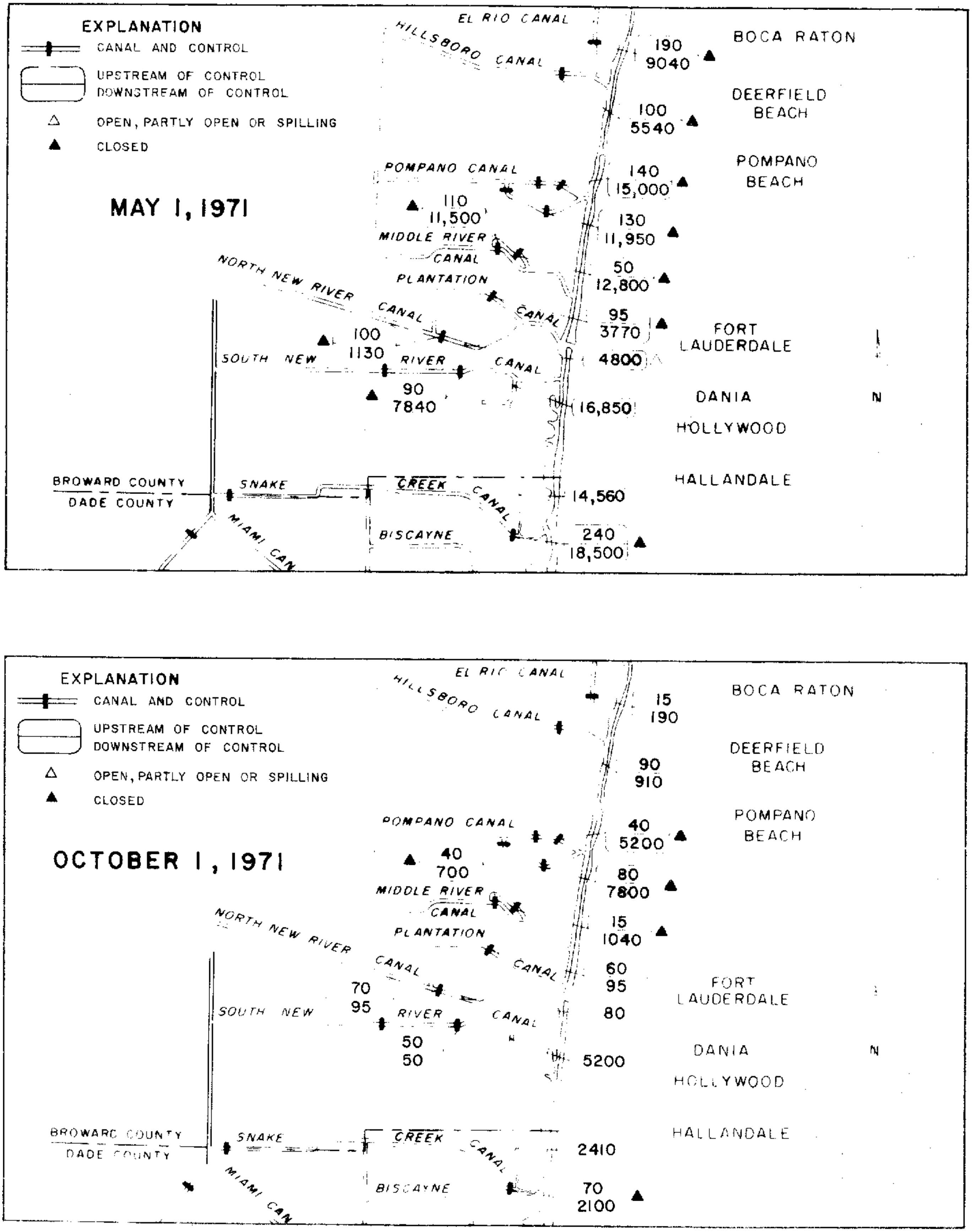


Figure 37.--Chloride content in canals at selected sites during low-water conditions, May 1, 1971 and high-water conditions, October 1, 1971.

When sea water moves into the uncontrolled reaches of the canal during low-water periods, it also infiltrates the aquifer. The approximate position of the saline front which varies slightly from low to high-water periods is shown on figure 38 for the coastal area of Broward County. The position of the salt-water front is determined by sampling test wells for chloride analysis (fig. 3) near the salt-water-fresh-water interface along the coastal areas. The chloride content in many of the wells varies greatly from low to high-water periods (table 3). Water from some of the wells increased in chloride and others decreased over the period of record (figs. 39 and 40). The wells with decreasing chloride content reflect the effects of better water management in that area. The wells with increasing chloride content generally reflect a lowering of the water level in that area by drainage or increased wellf-field pumpage.

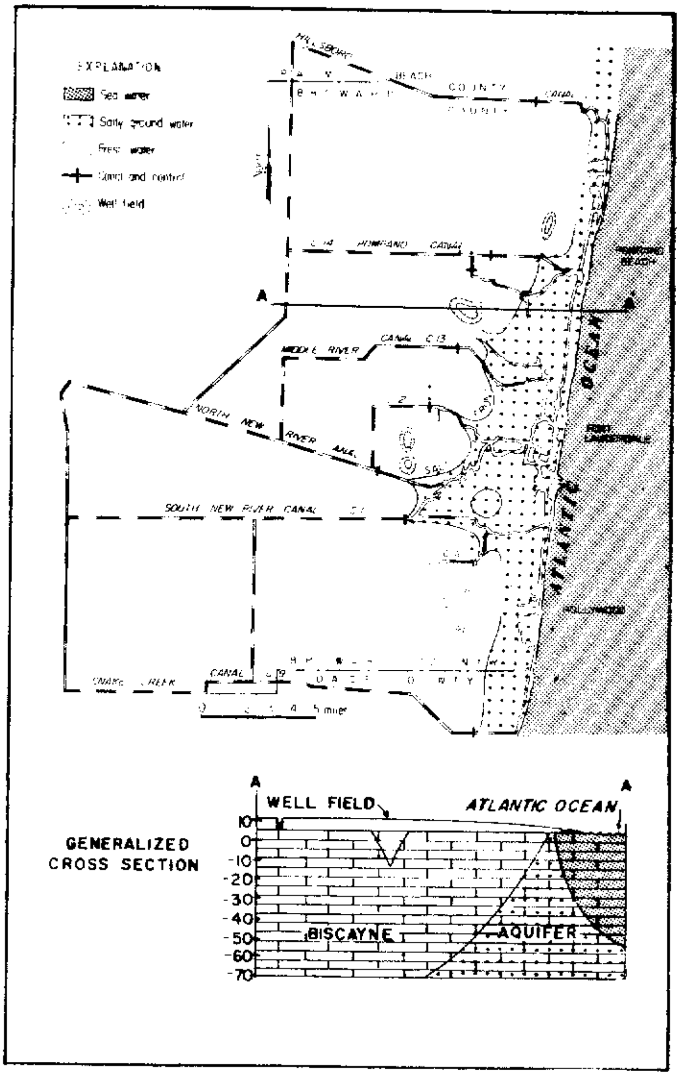


Figure 38.--Extent of sea-water intrusion, 1971.

Table 3.--Chloride content of water from wells in Broward County.

(milligrams per liter)

Well No.[1/]	Chloride Content: Low-Water Conditions 5-5-71	Chloride Content: High-Water Conditions 10-19-71	Date Record Began		Chloride Content: Period of Record Maximum	Chloride Content: Period of Record Minimum
S 830	2,700	1,500	Nov.	1946	2,800	
S 1321	50	46		1963	120	21
S 1325	205	110	Jan.	1957	262	18
S 1366	118	355	Oct.	1960	400	28
S 1370	38	42	Nov.	1967	73	33
S 1414	36	72	Mar.	1959	143	20
S 1488	25	23	June	1965	54	15
S 1489	40	22	June	1965	42	13
S 1524	84	121	Nov.	1970	121	52
G 515	685	680	April	1960	840	600
G 820	21	19	June	1956	41	14
G 854	690	595	Sept.	1959	860	155
G 941	82	60	Mar.	1959	112	64
G 1211	28	32	Aug.	1962	56	16
G 1212A	28	23	Aug.	1962	38	12
G 1231	840	500	Oct.	1967	1,860	370
G 1232	17	16	Nov.	1967	26	11
G 1235	760	442	Nov.	1967	880	442
G 1237	190	125	Oct.	1967	260	113
G 1240	230	227	Sept.	1967	250	154
G 1309	20	18	Nov.	1967	28	18
G 1340	86	100	Feb.	1968	177	72
G 1342	800	540	Mar.	1968	825	540
G 1343	60	52	Mar.	1968	130	48
G 1344	300	290	Mar.	1968	404	290
G 1346	190	126	June	1968	305	126

1/ For location of wells see figure 3.

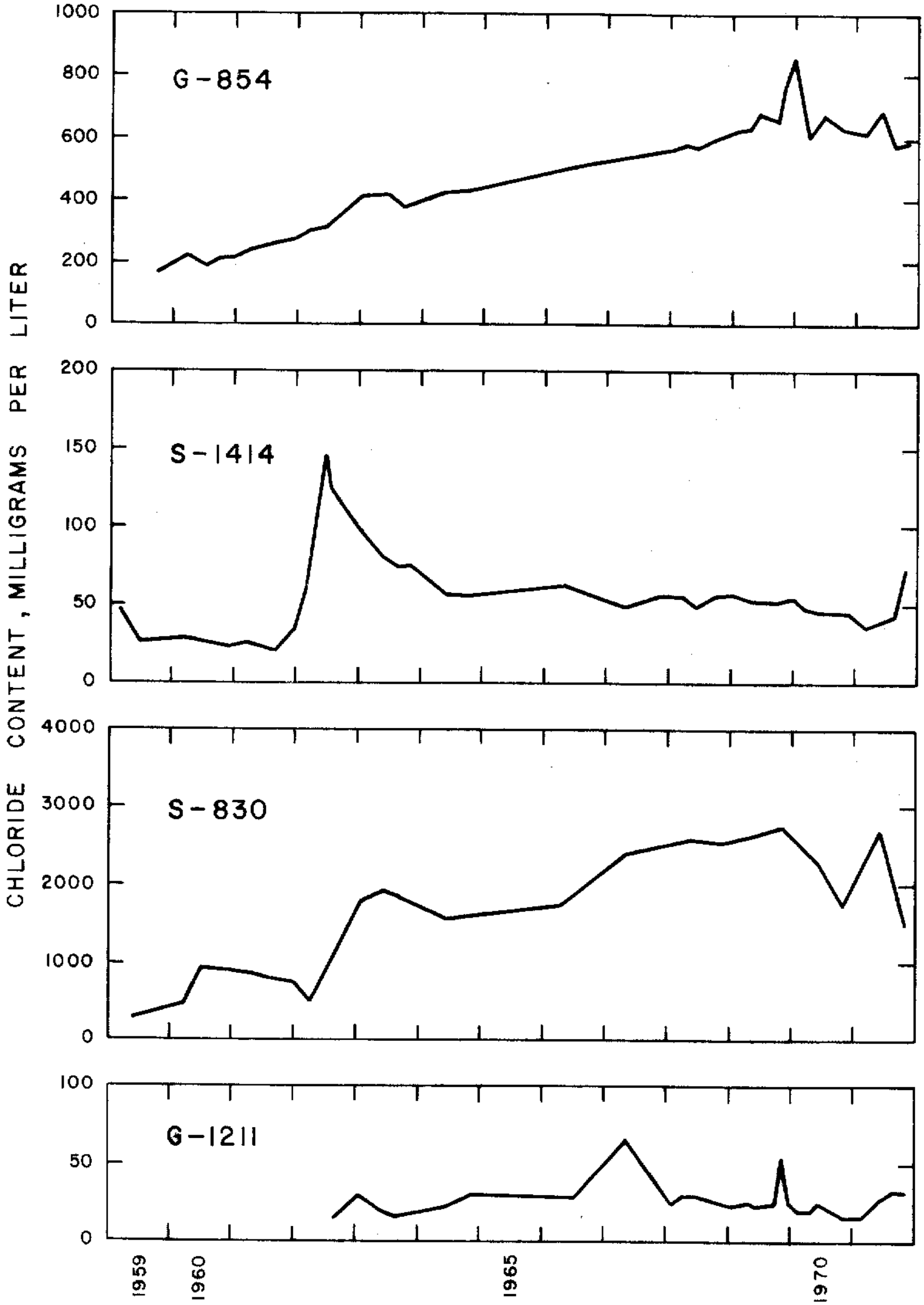


Figure 39.--Graphs of the chloride content of water in wells G 854, S 1414, S 830, and G 1211 in Broward County.

Table 4.--Raw water pumped by the major suppliers in Broward County in 1971.

City	Raw Water Pumpage (million gallons)
Fort Lauderdale	14,689
Pompano	5,421
Hollywood	5,166
Deerfield Beach	1,475
Hallandale	1,398
Miramar	734
Dania	501
Total	29,384

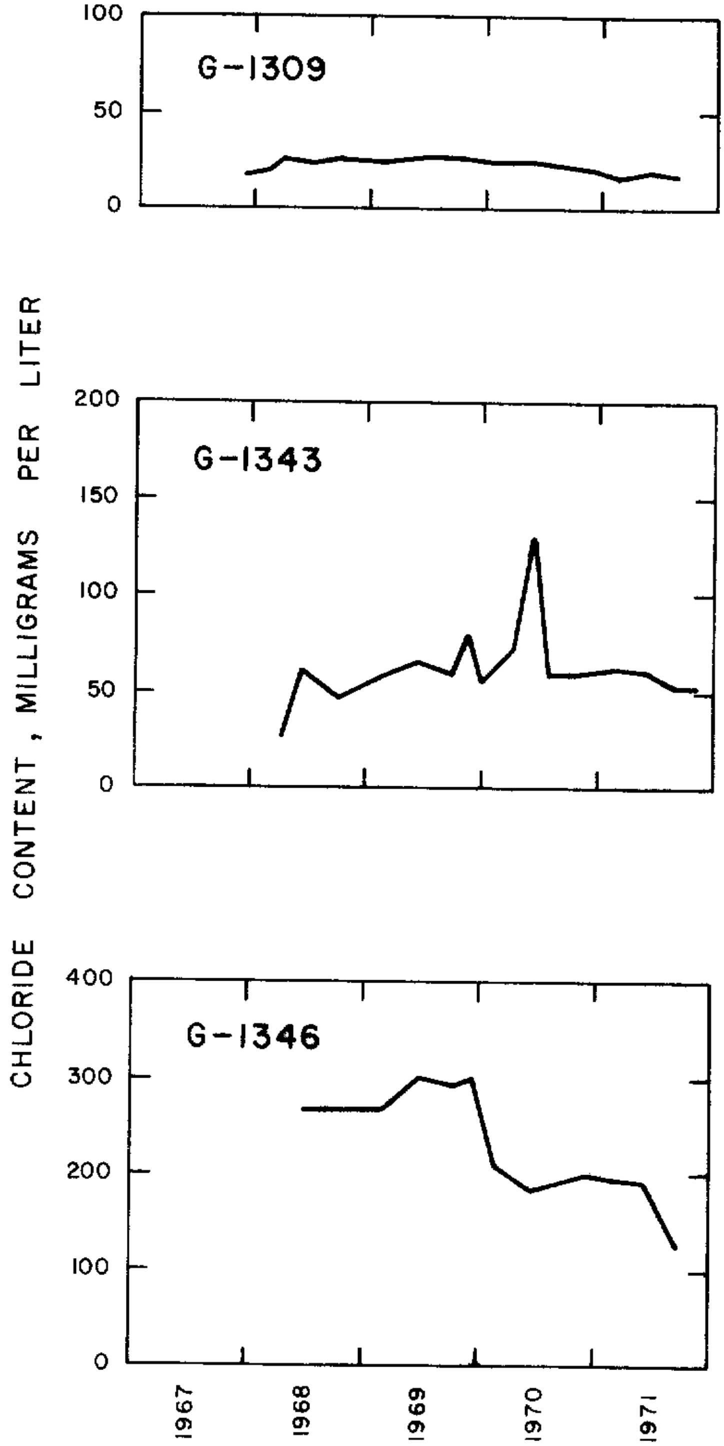


Figure 40.--Graphs of the chloride content of water in wells G 1309, G 1343, and G 1346 in Broward County.

WATER USE

All public supplies in Broward County are derived from wells. In the vicinity of many of the wells the aquifer is replenished in part by the infiltration of water from nearby canals. Most supplies in the urban area are provided by municipal systems, although some single and multi-unit domestic systems, are supplied by individual wells. It is estimated that between 30,000 and 35,000 private wells produce a total of 3.65 billion gallons per year (Sherwood, McCoy, and Galliher, 1972).

There are 32 municipal and privately owned utilities in Broward County that supply a permanent population of 500,000 and a peak tourist season population of about 900,000. During 1971 the seven largest suppliers (table 4) pumped 29.384 billion gallons or 80.5 million gallons daily for public supply. Pumpage has increased steadily since 1961 (fig. 41).

The water system of Fort Lauderdale, the largest in Broward County, has a capacity of over 60 mgd (million gallons per day). Fort Lauderdale's average demand in 1971 was 40.2 mgd, but the demand exceeded 60 mgd during the dry period in April. Monthly pumpages at Fort Lauderdale are highest during the dry season (December - May) because of heavy water use for lawn irrigation and increased demands caused by the influx of tourists. (fig. 42).

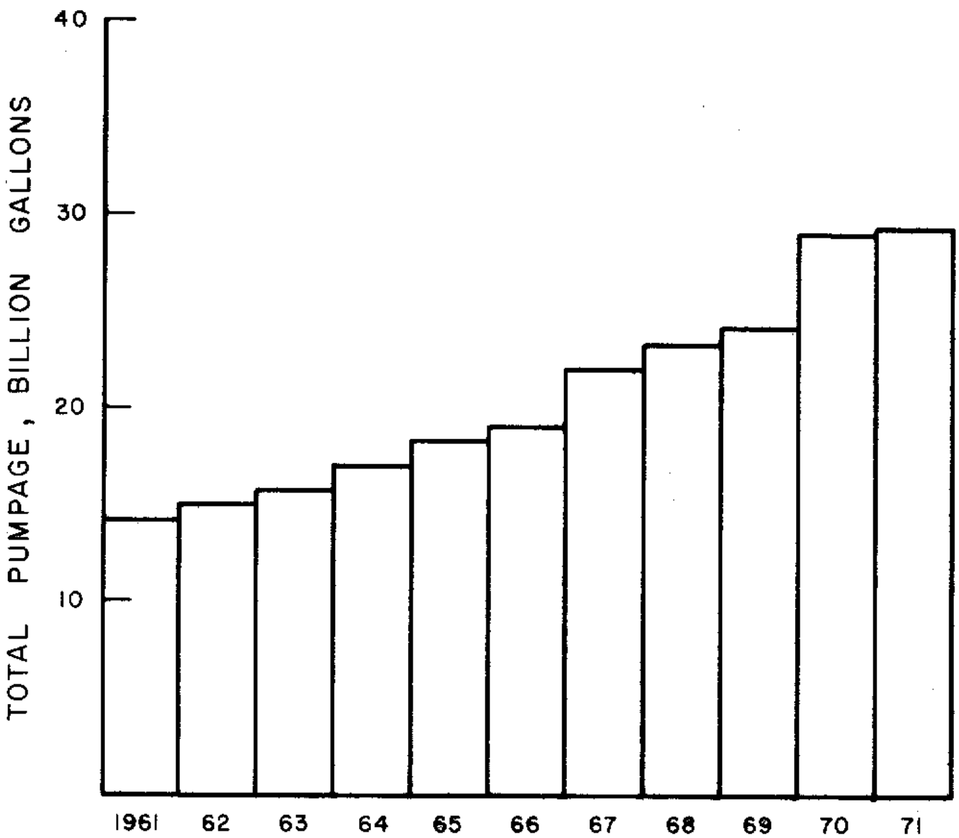


Figure 41.--Total raw-water pumpage from the Fort Lauderdale, Hollywood, Pompano, Hallandale, Deerfield Beach, Dania, and Miramar well fields, 1961-71.

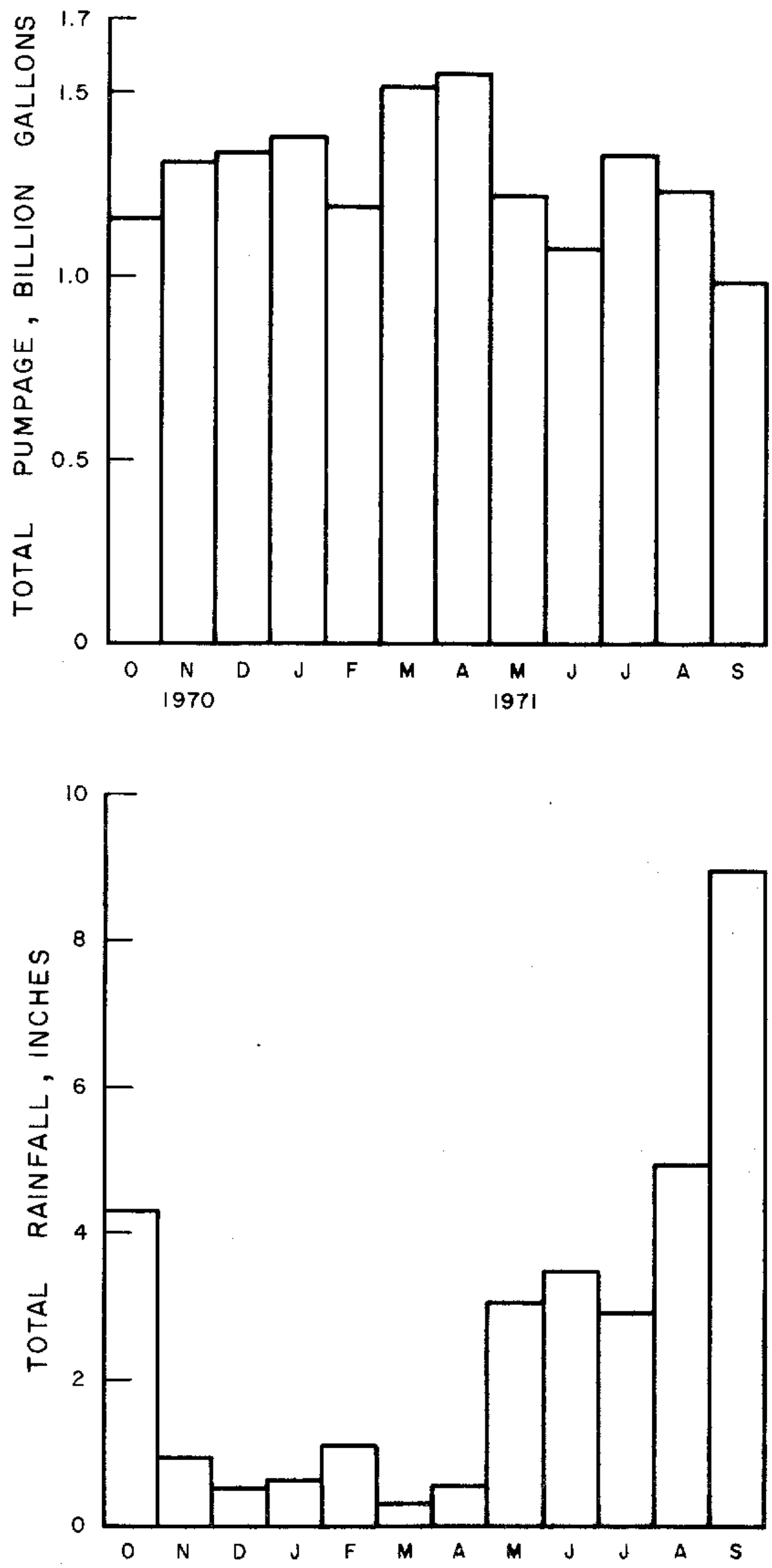


Figure 42 --Total monthly raw-water pumpage at the Fort Lauderdale Dixie and Prospect well fields, and total monthly rainfall at Fort Lauderdale, 1971 water year.

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